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EXPERIMENTAL

ELECTRICITY

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"EVERYBODY'S HAND-BOOK OF ELECTRICITY,"
—AND—
"HOW TO MAKE ELECTRIC BATTERIES AT HOME."

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PREFACE.

THE growing interest in electricity and its development to modern science, now being manifested by the public at large—also, the large numbers of amateurs who are daily springing up in all parts of the country—make it expedient at least in my mind to issue this volume, in which I shall endeavor as well as possible, avoiding technicalities, to give the reader in a simple way, practical directions for performing some easy and interesting experiments in electricity; also, for making some electrical apparatus by which he may obtain a considerable amount of practical information of the subject. I shall not in any way attempt to have him make highly finished appliances, such as are made by electrical companies having large factories, with machinery and tools at their disposal; but describe plain home-made appliances which, though roughly made, will give good results and prove I hope, satisfactory to their constuctor.

EDWARD TREVERT.

LYNN, MASS., May 1st, 1890.

CONTENTS.

EXPERIMENTAL ELECTRICITY.

CHAPTER I.

SOME EASY EXPERIMENTS IN ELECTRICITY AND MAGNETISM.

THE first knowledge of electricity came from the fact that when amber was rubbed it attracted light particles. This was discovered by the Greeks, and they called the amber electron. You may prove this by taking a piece of ceiling-wax, or of resin, or a glass rod, and by rubbing it upon a piece of flannel or silk, it will be found to have acquired a property which it did not previously possess: namely, the power of attracting to itself such light bodies as dust, or bits of paper, etc. Although a large number of substances possess this property, amber and jet were the only two in which its existence had been recognized by the ancients, or even down to so late a date as the time of Queen Elizabeth. About the year 1600, Dr. Gilbert of Colchester discovered by experiment

that not only amber and jet, but a very large number of substances, such as diamond, sapphire, rock-crystal, glass, sulphur, sealing-wax, resin, etc., which he styled electrics, possess the same property. Ever since his time the name electricity has been employed to denote the agency at work in producing these phenomena.

A good way to observe the attracting force is to employ a small ball of elder pith, or of cork, hung by a fine thread from a support, as shown in Fig. 1. A dry warm glass tube, excited by rubbing it briskly with a silk handkerchief, will

Fig. 1.

attract the pith ball strongly, showing that it is highly electrified. The most suitable rubber, if a stick of sealing-wax is used, will be found to be flannel, woolen cloth, or, best of all, fur. Boyle

discovered that an electrified body is itself attracted by one that has not been electrified. This may be verified (see Fig. 2) by rubbing a stick of sealing-wax, or a glass rod, and hanging it in a wire loop at the end of a silk thread. If, then, the hand be held out towards the suspended electrified body, it will turn round and approach the hand. So, again, a piece of silk ribbon, if rubbed with warm india-rubber, or even if drawn

Fig. 2.

between two pieces of warm flannel, and then held up by one end, will be found to be attracted by objects presented to it. If held near the wall of the room it will fly to it and stick to it. With proper precautions it can be shown that both the rubber and the thing rubbed are in an electrified state, for both will attract light bodies; but to show this, care must be taken not to handle the

rubber too much. Thus, if it is desired to show that when a piece of rabbit's fur is rubbed upon sealing-wax, the fur becomes also electrified, it is better not to take the fur in the hand, but to fasten it to the end of a glass rod as a handle.

When experimenting, as with a rubbed glass rod and bits of chopped paper, or straw, or bran, it will be noticed that these little bits are first

Fig. 3.

attracted and fly up towards the excited rod, but that, having touched it, they are speedily repelled and fly back to the table. To show this repulsion better, let a small piece of feather or down be hung by a silk thread to a support, and let an electrified glass rod be held near it. It will dart towards the rod and stick to it, and a moment later will dart away from it, repelled by an invisible

force (Fig. 3), nor will it again dart towards the rod. If the experiment be repeated with another feather and a stick of sealing-wax rubbed on flannel the same effects will occur. But, if now the hand be held towards the feather, it will rush towards the hand, as the rubbed body in Fig. 2 did. This proves that the feather, though it has not itself been rubbed, possesses the property originally imparted to the rod by rubbing it. In

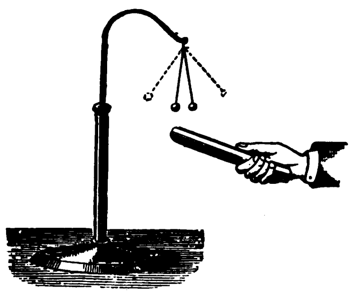


Fig. 4.

fact, it has become electrified by having touched an electrified body which has given part of its electricity to it. It would appear then that two bodies electrified with the same electricity repel one another. This may be confirmed by a further experiment. A rubbed glass rod, hung up as in Fig. 2, is repelled by a similar rubbed glass rod; while a rubbed stick of sealing-wax is repelled by a second rubbed stick of sealing-wax. Another

way of showing the repulsion between two similarly electrified bodies is to hang a couple of small pith-balls by thin linen threads to a glass support, as in Fig. 4, and then touch them both with a rubbed glass rod. They repel one another and then fly apart, instead of hanging down side by side, while the near presence of the glass rod will make them open out still wider, for now it repels them both. The self-repulsion of the parts of an electrified body is beautifully illustrated by the experiment of electrifying a soap-bubble, which expands when electrified.

THE ELECTROSCOPE.

An instrument for detecting whether a body is electrified or not, and whether the electrification is positive or negative, is termed an Electroscope. A very simple electroscope is made as follows: It consists of a stiff straw balanced lightly upon a sharp point (see Fig. 5).

A thin strip of brass or wood, or even a goose quill, balanced upon a sewing needle, will serve equally well. When an electrified body is held near the electroscope it is attracted and turned round, and will thus indicate the presence of quantities of electricity far too small to attract bits of paper from a table.

A still more sensitive instrument is the Gold-Leaf Electroscope invented by Bennett, and shown in Fig. 6. It is conveniently made by suspending two leaves within a wide-mouthed glass jar, which both serves to protect them from draughts of air and to support them from contact with the ground. Through the cork, which should be varnished with shellac or with paraffine wax, is pushed a bit of glass tube, also varnished.

Fig. 5.

Through this passes a stiff brass wire, the lower end of which is bent at a right angle to receive the two strips of gold leaf, while the upper supports a flat plate of metal, or may be furnished with a brass knob. When kept dry and free from dust it will indicate excessively small quantities of electricity. A rubbed glass rod, even while two or three feet from the instrument, will cause the leaves to repel one another. The chips produced by sharpening a pencil, falling on the electroscope top, are seen to be electrified. If the knob be even brushed with a camel's hair brush, the slight

friction produces a perceptible effect. With this instrument all kinds of friction can be shown to produce electrification. Let a person, standing upon an insulating support,—such as a stool with glass legs, or a board supported on four glass tumblers,—be briskly struck with a silk handkerchief, or with a fox's tail, or even brushed with a

Fig. 6.

clothes brush, he will be electrified, as will be indicated by the electroscope if he places one hand on the knob at the top of it. The Gold-Leaf Electroscope can further be used to indicate the kind of electricity on an excited body. Thus, suppose we rubbed a piece of brown paper with a

piece of india-rubber and desired to find out whether the electrification excited on the paper was + or −, we should proceed as follows:— First charge the gold leaves of the electroscope by touching the knob with a glass rod rubbed on silk. The leaves diverge, being electrified with + electrification. When they are thus charged the approach of a body which is positively electrified will cause them to diverge still more widely; while on the approach of one negatively electrified, they will tend to close together. If now the brown paper be brought near the electroscope, the leaves will be seen to diverge more, proving the electrification of the paper to be of the same kind as that with which the electroscope is charged, or positive.

The Gold-Leaf Electroscope will also indicate roughly the amount of electricity on a body placed in contact with it, for the gold leaves open out more widely when the quantity of electricity thus imparted to them is greater. For exact measurement, however, of the amounts of electricity thus present, recourse must be had to the instruments known as the Electrometers.

All these experiments are produced by what is termed frictional electricity.

MAGNETISM AND ELECTROMAGNETS.

The greatest of Gilbert's discoveries was that of the inherent magnetism of the earth. The earth itself is a great magnet, whose "poles" coincide nearly, but not quite, with the geographical north and south poles, and therefore it causes a freely-suspended magnet to turn into a north and south position.

Magnetism may be communicated to a piece of iron, without actual contact with a magnet. If a short, thin unmagnetized bar of iron, be placed near some iron filings, and a permanent magnet be brought near to the bar, the presence of the magnet will induce magnetism in the iron bar, and it will now attract the iron filings (Fig. 7).

Fig. 7.

In 1820, almost immediately after Oerstedt's discovery of the action of the electric current on a magnet needle, Arago and Davy independently

discovered how to magnetize iron and steel by causing currents of electricity to circulate round them in spiral coils of wire. The method is shown in the simple diagram of Fig. 8, where a current from a single cell is passed through a spiral coil of insulated wire, in the hollow of which is placed a bar of iron or steel, which is thereby magnetized. If the bar be of iron it will be a magnet only so long as the current flows; and an iron bar thus surrounded with a coil of wire for the purpose of magnetizing it by an electric current is called an Electro-magnet.

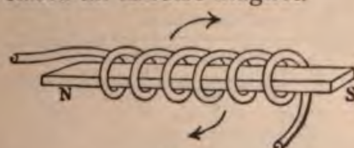


Fig. 8.

In 1819, Oerstedt showed that a magnet tends to set itself at right-angles to a wire carrying an electric current. He also found that the way in which the needle turns, whether to the right or the left of its usual position, depends upon the position of the wire that carries the current—whether it is above or below the needle—and on the direction in which the current flows through the wire.

Very simple apparatus suffices to repeat this experiment. Let a magnetic needle be suspended

on a pointed pivot, as in Fig. 9. Above it, and parallel to it, is held a stout copper wire, one end of which is joined to one pole of a battery of one or two cells. The other end of the wire is then brought into contact with the other pole of the battery. As soon as the circuit is completed the current flows through the wire and the needle turns briskly aside. If the current be flowing

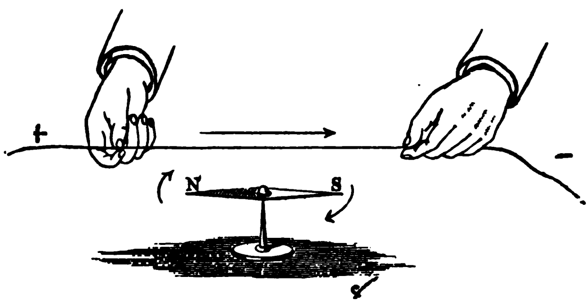


Fig. 9.

along the wire above the needle in the direction from north to south, it will cause the N.-seeking end of the needle to turn eastwards: if the current flows from south to north in the wire the N.-seeking end of the needle will be deflected westwards. If the wire is, however, below the needle, the motions will be reversed, and a current flowing from north to south will cause the N.-seeking pole to turn westwards.

CHAPTER II.

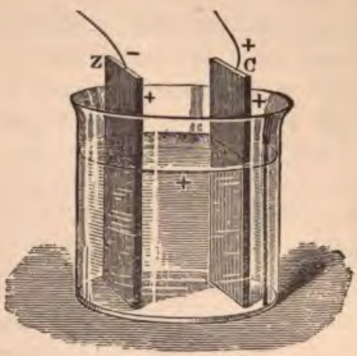
HOW TO MAKE ELECTRIC BATTERIES.

ELECTRIC BATTERIES may be classified according to their use into open circuit and closed circuit batteries. An open circuit battery is a battery which is used when a current is needed for a few seconds at a time. If the circuit is kept closed too long the battery will become polarized, that is, hydrogen will collect on the positive plates and prevent the current from passing through the circuit. If, however, the circuit is opened the battery will recover itself in time. These batteries are designed for bells, telephones, gas-lighters, etc.

Closed circuit batteries are used for continuous work, as for electric lighting, electro plating, fire alarms, etc.

The simplest electric battery made is the Voltaic Cell. This is made by placing in a glass jar some water having a little sulphuric acid or any other oxidizing acid added to it. Then place in it separately two clean strips, one of zinc Z, and one of copper C. This cell is capable of supplying a continuous flow of electricity through a wire whose

ends are brought into connection with the two strips. When the current flows the zinc strip is observed to waste away; its consumption in fact furnishes the energy required to drive the current through the cell and the connecting wire. The



The Voltaic Cell.

cell may, therefore, be regarded as a sort of chemical furnace in which the fuel is zinc. Before the strips are connected by a wire no appreciable difference of potential between the copper and the zinc will be observed by an electrometer; because the electrometer only measures the potential at a point in the air or oxidizing medium outside the *zinc or the* copper, not the potentials of the metals

themselves. The zinc itself is at about 1.86 volts lower potential than the surrounding oxidizing media; while the copper is at only about .81 volts lower, having a less tendency to become oxidized. There is then a latent difference of potential of about 1.05 volts between the copper and the zinc; but this produces no current as long as there is no metallic contact. If the strips are made to touch, or are joined by a pair of metal wires, immediately there is a rush of electricity through the metal from the copper to the zinc, and a small portion of the zinc is at the same time dissolved away; the zinc parting with its latent energy as its atoms combine with the acid. This energy is expended in forcing a discharge of electricity through the acid to the copper strip, and thence through the wire circuit back to the zinc strip. The copper strip, whence the current starts on its journey through the external circuit, is called the positive pole, and the zinc strip is called the negative pole.

This cell however is of little practical use, it being adapted only to experimental purposes, as it will rapidly polarize.

The bubbles of hydrogen gas liberated at the surface of the copper plate stick to it in great numbers, and form a film over its surface; hence the effective amount of surface of the copper plate is very seriously reduced in a short time. When a

simple cell, or battery of such cells, is set to porduce a current, it is found that the strength of the current after a few minutes, or even seconds, falls off very greatly, and may even be almost stopped. This immediate falling off in the strength of the current, which can be observed with any galvanometer and a pair of zinc and copper plates dipping into acid, is almost entirely due to the film of hydrogen bubbles sticking to the copper pole. A battery which is in this condition is said to be "polarized."

THE LECLANCHE CELL.

This cell is commonly used for what is termed open circuit work—that is to say, for work in which the circuit is open most of the time and the battery sends a current for a short time only between long periods of rest. It has an internal resistance of about 3 ohms, and an E.M.F. of 1.5 volts. It will therefore give a stronger current than the gravity cell, but, as stated above, for only a short time. While not sending a current, it does not deteriorate as does the gravity cell, and it requires almost no attention beyond occasionally filling it up with water, and once in six months or so adding some sal ammoniac. It is not so easily made

as a gravity cell but is more convenient for many purposes.

A porous cup of some description must be had to hold the carbon element. It should be about six inches high and two or three in diameter. It must be of unglazed earthen ware in order that the liquid may penetrate it.

Persons who are near a pottery can generally find something suitable there, but when nothing better can be had, a long narrow flower-pot with the hole in the bottom plugged up will do.

The carbon can be sawed from a piece of "gas carbon," which can be obtained from any gas works. It must not be confused with the coke left from making the gas, but is the deposit on the inside of the retorts which is much denser and finer grained than the coke, as well as being purer carbon. A piece must be cut out which will go easily inside the porous cup, and when touching the bottom, project two inches from the top. It should be about twice as wide as it is thick.

The top end of the carbon should be paraffined to prevent the formation of high resistance lead salts between it and its cap. This is done by dipping the end of the carbon into melted paraffine and keeping it there for an hour. The temperature of the paraffine can be kept right by putting

the vessel in which the paraffine is melted, into boiling water.

Next drill two quarter-inch holes through the paraffine end, equally distant from each other and the sides of the carbon, and three-quarters of an inch from the end.

We shall next need a mould for the leaden cap. Take a block of wood and make it a quarter of an inch wider and a quarter of an inch thicker than

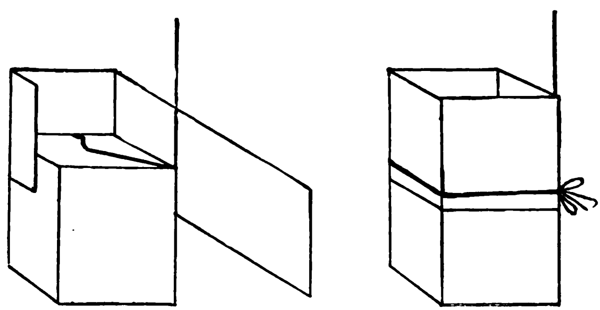


Fig. 1.

the carbon. Then take a strip of stiff heavy paper and wrap it around the end of the block as shown in Fig 1, the paper projecting an inch and a quarter above the end of the block. First however a copper wire should be tacked to the block in the position shown, the end in the middle sticking up a quarter of an inch, and the wire being pressed close into the corner of the paper where it comes out of the

box. Now pour melted lead into this box until it is half full, and then press the paraffined end of the carbon into the lead until it rests upon the wire in the bottom of the box and let it stand until cool, when the paper can be removed and the wire attached to the lead straightened out. The lead will run into the holes and hold the cap on firmly, and it should look as in the cut, Fig 2.

Fig. 2.

If it is not convenient to make a lead cap, a single hole may be drilled through the end of the carbon about three-quarters of an inch from the end and a round-head wood screw put through it, and screwed into a wooden block on the other side. The wire can be placed under the head of the screw and so clamped to the carbon, see Fig 3.

This however does not make so good a contact as the first.

Now break up some gas carbon into bits about the size of a pea, and after sifting them to remove the dust, take enough to fill up around the carbon in the porous cup and mix with it about half as much peroxide of manganese in the needle form, which should also be sifted. Pack the mixture tightly around the carbon in the porous cup.

In the commercial form of this battery the top of the cup is now sealed over with pitch, a hole being left for pouring in water to start the battery. A

Fig. 3.

simpler covering may be made of card board, which is cut out to receive the carbon rod and extends to the edge of the porous cup.

For the zinc element we will need a piece of sheet zinc as wide as the porous cup is long, and long enough so that when rolled up in a cylindrical form it will go around the cup, but not touch it. A wire should be soldered to the top of the zinc.

For our cell we shall need a jar preferably of glass, which shall be large enough to contain the zinc and cup. Put the zinc inside this jar, and inside the zinc cylinder the porous cup.

The battery complete is shown in Fig 4.

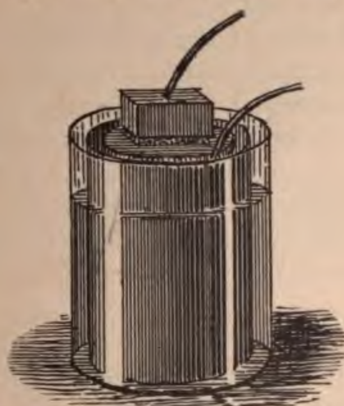


Fig. 4.

Now put in 4 oz. of sal ammoniac and add water until the jar is three-quarters full, and also pour a little into the porous cup, and leave the battery for three or four hours, when it should be ready to give a current. When the liquid becomes weak, and more sal ammoniac is needed, it will show it by becoming milky in color.

Trouble is sometimes experienced with the battery from creeping salts. The paraffine remedy

spoken of in connection with the gravity cell can be applied here too.

Another method is to avoid the creeping altogether by using a dilution of sulphuric acid in water (1 part acid to 40 of water) in place of the sal ammoniac solution.

A modification of the Leclanche Cell is sometimes used, which is said to have a higher E.M.F., and a lower internal resistance. In place of the broken gas carbon and peroxide of manganese, the carbon rod is packed around with the so called chloride of lime, or bleaching powder, and the liquid, instead of being a solution of sal ammoniac, is a solution of common salt.

THE GRAVITY CELL.

For a person with limited facilities at hand, the Gravity Battery will probably present the fewest difficulties in making and will be the most satisfactory for all-around work. Its internal resistance is comparatively high (generally about 8 ohms) and it has an electro-motive force of only a volt, but it can be used as few others can for producing a steady current for a long time, or in other words, is what is commonly called a closed circuit battery. The elements used are zinc and copper, and the liquids, solutions of copper sulphate and zinc sulphate.

The battery may be cheaply constructed as follows :—Procure a jar the size you wish your cell to be — it may be of glazed earthenware or glass, preferably the latter, so that the condition of the cell may be seen from time to time. It may be of almost any size but it will be well to have it somewhere near eight inches high and six in diameter. The size of the cell governs the amount of current that may be obtained from it, for while the electromotive force of a cell of any size is the same, providing the elements are the same, the internal resistance is increased as the cell grows smaller, which will of course reduce the current. So it would be well not to make the cell too small, and at the same time it should not be made very much larger than the dimensions given, since it would then become rather unwieldy, and the same results, viz., the lowering of the resistance can be secured by using two or more cells and connecting them in multiple. The jar should have a mouth nearly or quite as large as its body to facilitate placing the elements inside it. Should nothing else be available, a large bottle can be made to do by cutting off the neck and upper part.

To do this, make a file mark on one side of the bottle where you wish to cut it, and take a heated iron rod, which has been previously bent for a short distance to follow the curve of the bottle, and

placing the end of the rod at the file mark and the curved part against the glass where you wish it to crack, roll the bottle on a board or table. If it does not immediately crack, let a drop of water fall on the file mark and then draw the iron around the bottle when a crack will follow it.

The jar being provided, next get some sheet copper for the copper element. It is not necessary to have this very thick as it is not consumed in the battery. For the size jar spoken of above, the copper should be a strip two inches wide, and may be rolled up in the form of spiral, as shown in Fig. 5.

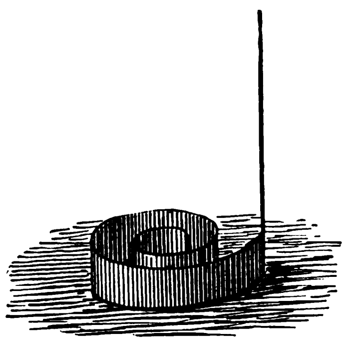


Fig. 5.

A copper wire should be soldered or riveted to the copper strip long enough to reach outside of

the jar, and it should be insulated to prevent contact with the zinc element. The zinc element should be heavier than the copper as it is consumed while the battery is in action.

To make it, lay out a star-shaped figure on a board, by first drawing a circle on it, half an inch less in diameter than the inside diameter of the jar. Lay off the length of the radius of this circle around the circumference, and you will obtain six points from which to draw lines to the centre of the circle, as in Fig. 6.

Fig. 6.

With a round chisel gouge out grooves along these lines, say an inch wide and three-quarters deep, and you have a mould for the zinc element. Melt up some zinc in an iron ladle, and after standing a copper wire up in the centre of the mould, as shown in Fig. 7, pour in the zinc.

When it is cool it should be dipped in acid to clean it, or if acid is not at hand it should be thoroughly rubbed with sand-paper and then a little mercury rubbed on it until the whole surface pre-

sents a smooth and bright appearance. This is called amalgamation, and while not absolutely essential is advisable in order to prevent what is called local action, which consumes the zinc without furnishing any useful current.

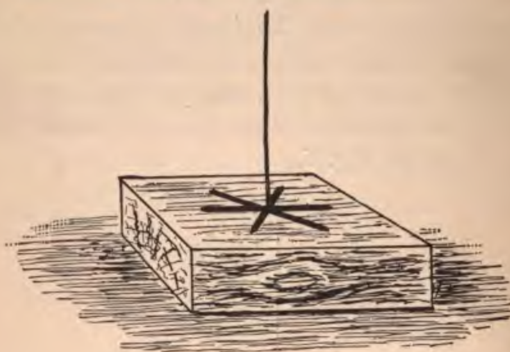


Fig. 7.

The wire from the top of the zinc can now be run through a square stick and bent at right angles on the other side to prevent its being pulled back by the weight of the zinc, and the zinc is now ready for use. In running the wire through the stick its length should be so adjusted that when the stick rests upon the top of the jar, the top of the zinc is an inch below the top of the jar.

Fig. 8 shows the elements in place in the jar. An easier way to make the zinc element,

is to take sheet zinc such as is used to go under stoves and cut a strip an inch and a half wide. Its length will vary with the size of the jar, and can best be found by trial. Bend it as shown in Fig. 9, leaving the ends long enough to go over the

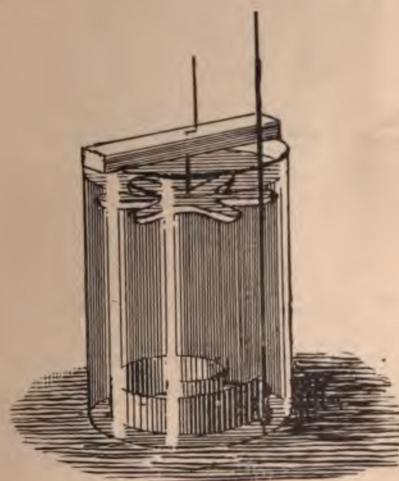


Fig. 8.

top of a stick and allow the zinc to hang with its top an inch below the top of the jar when the stick is resting on it. The ends of the zinc should be screwed to the stick with round-head wood screws and a wire placed between the head of one of the screws and the zinc.

This style of zinc element will give good results while it lasts, but that will not be very long if the battery is used constantly. It is, however, easily replaced, and where the making of the other kind is not convenient, will be a fair substitute for it.

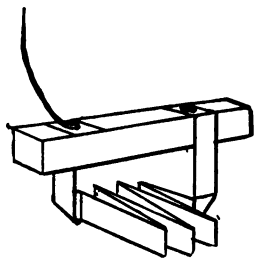


Fig. 9.

The battery is now ready to set up. Place the copper element in the bottom of the jar and around it enough crystals of copper sulphate, or blue vitriol, to half cover it. Then put in the zinc, letting it hang by its stick placed across the top of the jar. Fill up the jar with water until the zinc is covered, and immediately short circuit the battery,—that is, connect the wire from the copper to that from the zinc. Let the battery stand so for six hours when it should be ready for use. A little zinc sulphate added to the water will hasten the action. The copper sulphate on dissolving will give a blue ap-

pearance to the water in the lower part of the jar. The condition of this blue part is an index to the condition of the battery. In a well kept cell it will rise about half-way between the copper and zinc. It should never be allowed to touch the zinc for if it does it will deposit copper on it and this will injure the action of the cell. If the blue line is getting too high it can be made to lower by temporarily short circuiting the battery. If it is too low, that is, so that the copper shows above it, more crystals of copper sulphate must be added and a little of the clear liquid at the top drawn off and water added to take its place.

An annoyance which will probably be experienced is from what is termed "creeping" of the salts. A mass of white crystals will form about the rim of the jar, and will spread unless checked, until they cover the outside of the jar. This may be partly prevented by dipping the rim of the jar in melted paraffine.

The battery will work best when kept constantly at work. If left idle for some time the blue and white liquids will tend to diffuse or mix, which is detrimental to the action of the cell. If the battery is to be left unused for a long time it is best to put a resistance of some sort between the ter-

minals, which will keep the battery in order and at the same time not use enough current to run it down.

PLUNGE BICROMATE BATTERY.

One of the simplest, best, and most inexpensive batteries to make where a strong current is wanted for a short time only, is a Plunge Battery. This can be made in the following manner:

Take 4, 6, 10, or any even number of common tumblers, and arrange them in two rows parallel to each other. The tumblers to be held in place by an apertured board supported a short distance above the base-board by round standards. To these fit a board which is split from the standards outward, and provide it with two bolts with wing nuts, by which the board may be clamped at the desired height. Now take as many plates of carbon, about 1 1-2 inches wide, 1-4 inch thick, and 6 inches long, as you have tumblers, and saturate one end of them with a little melted wax or paraffine to keep the salts from creeping. When they are cool fasten the paraffine ends to the opposite edges of the movable board, interposing between the carbon plate and the edge of the board a copper wire. The wooden strips by which the carbons are clamped should be about one-half of an inch thick. Take

as many zinc plates as you have carbon plates, taking care to have them the same size as the carbon plates, and amalgamate them. This can be done in the following manner :

Take a little diluted sulphuric acid and give your zinc plates a bath in it, then rub a little mercury into the pores of the zinc with a small tooth brush. Having done this the zincs are ready for use.

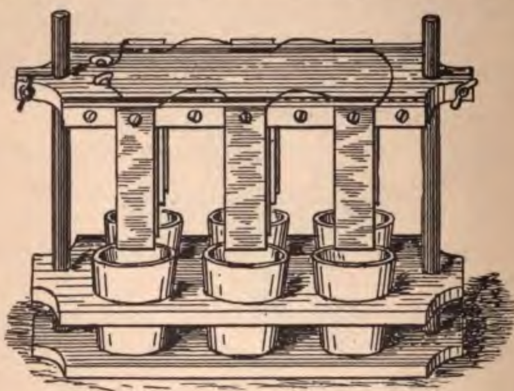
Secure the zinc plates to the outside of the wooden strips by which the carbons are clamped.

Fig. 10.

This can be done by ordinary one-half inch screws, passing them through holes in the zinc into the wood. Connect the copper wire of one carbon plate to the zinc of the next, and so on throughout the series. The terminal plates to be connected to two binding posts, which can be made by soldering flat pieces of brass into the heads of round-head wood screws, and screwing them into the wood with the wire under the head. (See Fig. 10.)

Fill the tumblers about two-thirds full of bicromate solution. To make this solution proceed as follows:

To three pints of cold water add five fluid ounces of sulphuric acid. When this becomes cold add six ounces (or as much as the solution will dissolve) of finely pulverized bicromate of potash. Mix well.



The Plunge Battery Complete.

Always pull your plates out of your solution when your battery is not in use, as the zinc is continually being eaten away when it is in the solution. Each cell will give an electro-motive force of about 2 volts.

This battery can be used for running a small incandescent lamp, or motor. A battery of six cells

will run a small five or six volt incandescent lamp quite a little while. A much stronger battery can be made by using larger tumblers, or fruit jars and proportionately larger zincs and carbons.

THE STORAGE CELL.

This battery has many advantages over the primary battery. For places where a large current is required, such as for running lights or motors, it can be used much more economically than a primary battery, since it has a low internal resistance, and in a well made battery the plates should not deteriorate to such an extent that they have to be thrown away for a long time. It is, however, much more expensive to make, and a good deal of trouble to look after, and when one has not access to a direct current dynamo of some sort, it would be almost out of question to attempt to do any thing with it. However, supposing the reader to be near some electric installation where he can tap a current, we will give him directions for making the battery.

There are two forms of storage battery in use now, that with unpasted and that with pasted plates. We will confine ourselves to the former—for while the latter has many advantages, such as higher E.M.F., greater power for a given weight, etc., the other is more easily made by a person

with few tools, and is safer in the hands of a beginner, as it may be short circuited for a little while without damaging it.

A round glass jar (a large fruit jar will do), is the first thing necessary. Of course the remarks made before about the size of the battery and quantity of current to be obtained from it apply here, also. Care must be exercised, however, if the cell is to be large, to get it thick and strong enough to stand the weight of the lead inside without breaking. For the plates we shall need some strips of sheet lead about one-sixteenth or three-thirty-seconds of an inch thick, and about an inch less in breadth than the height of the jar. The length of these strips can best be determined for each case by experiment. Take two of these strips and lay them on a table, as shown in Fig. 11,

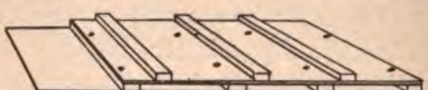


Fig. 11.

with paraffined sticks a quarter of an inch thick and three-eighths of an inch wide, in the position shown. Their number will depend upon the size of the cell. They should be placed about three inches apart. The end stick should be tacked to both top and bottom plate, care being taken that the tacks do not go clear through the wood, and

touch the opposite plate, or that two tacks from the opposite sides do not touch each other. The other sticks should be tacked to the top plate only with two tacks to each stick. Now, beginning at the right hand, roll up the plates together until you have a roll which will just go inside the jar, and cut off what is left. (See Fig. 12.) A stick should be placed

Fig. 12.

between the free ends and tacked to one of the plates. Now unroll your plates, and if you are going to make any more cells of the same size cut your lead strips by these. Take a coarse file and laying it upon the lead strip, which in turn is on a soft board, pound the file with a mallet, moving it about over the lead until the whole surface has a

roughened appearance. Then turn it over and repeat the treatment on the other side. Fix both plates this way, and then roll them up again, being careful that the plates do not touch each other but are kept separate by the sticks, and put them in the jar. Fill the jar with a mixture of equal parts of water and nitric acid, and let the lead plates stand in it for a day, when they should be removed and thoroughly washed.

This treatment gives the surface of the lead a porous or roughened appearance, and thus increases the surface which may be acted upon by the current. Now turn out the nitric acid, and place in the bottom of the cell a stick a quarter of an inch square, which has been boiled in paraffine. This stick is to keep the lead from the bottom of the cell, and thus prevent short circuiting from the fine powder which may fall from the plates. Solder a wire to the top of each of the lead plates, and put the plates on the stick, and fill the jar with diluted sulphuric acid (1 part acid to 10 of water) which has been mixed four or five hours previously.

In mixing the acid, care must be taken or it may fly up and go over the face or clothes. The acid should be poured in a fine stream into the water.

Your battery is now ready to charge. The method of doing this will vary with the circumstances. If you have a large number of batteries,

say 45, and a constant potential dynamo supplying current at 110 volts, the cells may be connected up in series, and placed directly between the mains. When first starting up, or when reversing the cells, it would be well to have a resistance of say 20 ohms in series with the cells which can be cut out when the cells have become formed sufficiently to oppose the current with their normal voltage. This can be seen when one set of plates turn a chocolate color.

The Storage Cell Complete.

Should you have a fewer number of cells, and the 110 volt circuit at command, insert a resistance in series with the battery, which will cut down the

charging current to about 5 amperes for the fruit jar size cell.

When the number of your cells is small, charging from a constant potential circuit of 110 volts becomes very wasteful, on account of the large amount of energy used up on the resistance. Under such circumstances if an arc current is available, it would be well to use that, and in fact it could be used to advantage with a large number as well as a small number of cells.

If it is a current of from 5 to 7 amperes, your cells may be connected in series with each other and the circuit.

If a larger current, say of 10 amperes is used, then the cells should be connected by twos in multiple, and the twos in series in such a way that each cell will receive about 5 amperes.

If you only have one cell and a 10 ampere current, shunt the cell with a resistance of about half an ohm and connect the terminals into the circuit.

We are supposing the most probable cases where a person lives near a lighting station or installation. Any dynamo that can pass a current of from 5 to 10 amperes through the cells may be used, but as there are so many ways in which this can be done, no specific directions can be given that will fit each case. A smaller current may be used, and this is one of the beauties of this cell. It can

be charged with a small current for a proportionally longer time, and then give out a large current for a short time.

Having decided upon the best means of charging our cell we begin by passing a current through it in one direction for from 20 to 30 hours—not necessarily continuously, but preferably so. If the cells begin to boil violently after a short time, the current should be reduced, not that boiling hurts the cell, but it wastes energy. Moderate boiling is not harmful, and is an indication that the cell is working well.

After charging for the specified time, let the cell rest for five or six hours and then discharge it through a resistance that will allow 5 or 10 amperes to pass, and as soon as the cell is discharged begin to charge in the opposite direction, and let it go on for the same length of time as before, after which, let the cell rest again and then discharge. Charge again in the opposite direction and repeat the operations given above until the cell has been discharged four times, when it should be "formed." Now charge again for five or six hours in the same direction that it was last charged and the battery is ready for business.

Each cell should give about 2 volts, a little above this at first, and a little under towards the end of the discharge. It should never be allowed to dis-

charge after the E.M.F. has dropped to 1.8 volts per cell. It should never be allowed to stand discharged. After using it for awhile, charge up again, and if the cells are to stand idle for a long while they should be charged every month, to compensate for the losses from leakage.

When a cell is charged it is shown by the liquid boiling briskly. The current passed through it after that is nearly all wasted, but a little more may be forced in by stopping the charging current for a while and starting up with the current diminished. After the cell has once been formed the charging should always be done in the same direction.

If the cell has been left discharged for some time, or the acid solution becomes too weak, the positive or chocolate colored plates will "sulphate," or turn a grayish color. This may be remedied by overcharging the battery, which means to continue to pass a current through it after it has commenced to boil. This should be done until the last trace of the sulphate has disappeared.

The battery will lose a great deal of its liquid by evaporation and decomposition, and should be filled up with water as soon as its level gets much below that of the top of the plates.

CHAPTER III.

HOW TO MAKE A GALVANOMETER.

THE galvanometer at present exists in a large variety of forms dependent upon the particular uses to which it is to be applied.

We will describe but one which will answer for all ordinary purposes and be the easiest to make with the materials generally at hand.

A pocket compass, such as can be had at any optician's, will be necessary. They cost all the way from twenty-five cents to two or three dollars, the cheaper kind being without jewels for the pivots to work in. The jewels are not essential, but add greatly to the freedom of movement of the needle and therefore to the sensibility of the instrument.

With the compass before you, take two strips of sheet brass $\frac{1}{32}$ of an inch thick and $\frac{5}{8}$ of an inch wide and bend them into rectangles which will just allow the compass to pass through the openings.

Bevel off the ends of each strip where they come together and solder them (Fig. 1).

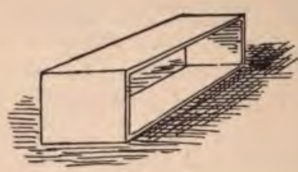


Fig. 1.

Then cut two pieces of the same thickness sheet brass a half an inch wider and a half an inch longer than the openings in the pieces you have already fixed and two more of the same length as the last pieces, but a quarter of an inch wider still.

Bend these last two pieces at right angles a quarter of an inch from one of the long sides and drill two holes for screws in each of the short legs of the angles (Fig. 2).

Cut a hole in the middle of the strips which were not bent and in the middle of the long leg of the pieces which were bent, which will just allow the first piece you prepared to slip in as shown (Fig. 3).

Put one of the flat pieces and one of the angles on each end and solder them there and you will have two spools on which to wind the wire.

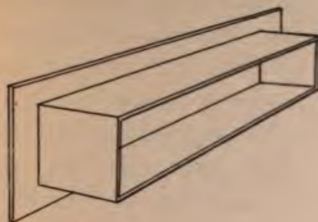


Fig 3.

Fig 2.

They must, however, be insulated before any wire is put on, so paste a thickness of writing paper on the interior surfaces which the wire will touch.

Bore a $\frac{1}{16}$ inch hole in one flange of each spool close to the bottom of the channel.

The wire should be chosen for the particular kind of work for which the galvanometer is to be used, but without knowing just what this will be we say that for the uses the galvanometer is likely to be put to by the amateur, somewhere in the neighborhood of No. 22 to No. 25 will do.

It should be copper and covered with cotton or silk.

Push about six inches of the wire through the hole in the flange of one of your spools from the inside, and where it goes through the hole wrap a little cloth around the wire. Then bend the wire sharply at the hole so that it will not pull back

and begin to wind on. Do this carefully so as to keep the wire tight and smooth and packed closely. As you are commencing to put on the next to the last layer, tie a string around the first turn and leave the ends hanging and when you return to that end on the last layer, tie down the last turn with these ends and cut off the wire about six inches from the tie.

Do the same with the other spool.

Now place the spools on a block so that the coils will be parallel and about one-half the diameter of your compass apart. Screw them down to the board.

It would be well now to run each of the four ends of the windings to a separate binding post on the base board to admit making the different connections which may be necessary.

Put your compass in the hole in the spools and adjust it so that the pivot is midway between the spools and the north and south line parallel to them.

The compass had better be wedged in place by a bit of paper.

Now connect your coils in series and in such a way that the current will pass in the same direction in each; then turn the galvanometer around until the needle stands directly over the north and south line.

Pass a small current through the galvanometer, enough to deflect it about 20^0 and note the deflection.

Then reverse your current and take a reading on the opposite side. If the compass box has been properly adjusted these will be equal.

If they are not equal the box must be turned a little with reference to the coils and the whole instrument turned so as to bring the needle again on the zero or north and south line when the current is off.

Care must be taken to have the current from a source which can be depended upon as steady for a long enough time to get the reading, and any way it would be well to reverse several times and take a number of readings before shifting the box.

An instrument of this description cannot well be used to measure a current in amperes and its principal utility is in detecting currents, showing their direction and to a certain extent comparing their strength.

If it is to be used simply as a detector the coils should be brought much closer together, leaving just space enough to allow the needle to be seen between them. Then as soon as a current is passed through the coils it is shown by the needle moving.

The direction of the current may be ascertained by Amperes' Rule, which is to imagine yourself swimming in the wire and facing the needle. If the north pole is deflected to the left you are swimming with the current, if to the right you are against it.

The detector finds its principal use on the Wheatstone Bridge.

Whenever it is desired to make a comparison of two currents, a larger amount of the scale must be shown and the coils must be placed farther apart as directed at first.

For small deflections the tangent law is roughly followed on a galvanometer like this, that is to say the currents producing two deflections are proportional to the tangents of the angles of deflection.

A table of natural tangents should be at hand to make the comparison with, but supposing the reader does not possess one we give a small table for every degree up to 30 and also one of sines which will be referred to later.

To show the use of the table take an example:

Suppose with one current a deflection of 10° is read and with another a deflection of 15°. We wish to know what are the relative strengths of

current. Looking up the tangent of 10° in the table we find .176 and for the tangent of 15° we get .268.

DEG.	TANG.	SINES.	DEG.	TANG.	SINES.
1	.017	.017	16	.287	.276
2	.035	.035	17	.306	.292
3	.052	.052	18	.325	.309
4	.070	.070	19	.344	.326
5	.087	.087	20	.364	.342
6	.105	.105	21	.384	.358
7	.123	.122	22	.404	.375
8	.141	.139	23	.424	.391
9	.158	.156	24	.445	.407
10	.176	.174	25	.466	.423
11	.194	.191	26	.488	.438
12	.213	.208	27	.510	.454
13	.231	.225	28	.532	.469
14	.249	.242	29	.554	.485
15	.268	.259	30	.577	.500

Then by simple proportion we have the first current is to the second as .176 is to .268, or dividing the former by the latter we get .65 nearly, which shows that the first was .65 as strong as the second.

But as we said above, the approximation to the tangent law is very rough and it will be more satisfactory to use the instrument as a sine galvanometer.

Be sure that the compass box is accurately adjusted according to the directions given above,

and then turn on the current which should not give a very large deflection. Turn the coils around in the direction the needle was deflected until the needle again stands on the zero.

Then take off the current and read the degrees when the needle comes to rest.

The strength of the current is proportional to the sine of these degrees.

Suppose you desire to compare two currents. You follow up the needle with the coils until it is on zero, and then remove the current and note where the needle comes to rest on the scale.

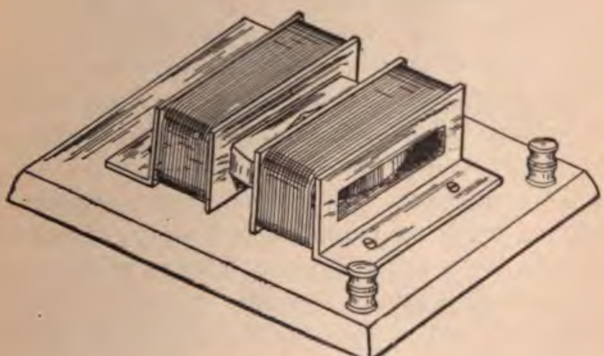
Then send the other current through the instrument and again follow up the needle until it comes to zero and take a reading when the current is off.

These two currents will be to each other as the sines of these deflections.

Suppose the first reading to have been 30^{0} and the second 25^{0}. The sine of 30^{0}, according to the table is .5 and of 25^{0} is .423. .5 divided by .423 is 1.2 nearly, or the first current was 1.2 times the strength of the second.

The sensibility of the galvanometer can be varied by connecting the coils in series for smaller and in multiple for larger currents.

If the current is even then too large, a shunt across the terminals can be arranged to relieve it of any desired amount.

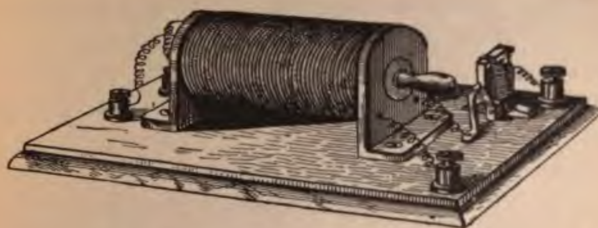


THE GALVANOMETER.

CHAPTER IV.

HOW TO MAKE AN INDUCTION COIL.

The Induction Coil is a piece of apparatus generally used to change the electro-motive force of a source of electric energy to some other value. The electro-motive force may be either raised or lowered. The first is the use to which what is ordinarily known as the induction coil is put, while what is known as the transformer (which is just as much an induction coil as the other), is used to lower the voltage in lighting mains to a value which is safe to introduce into houses. The coil which carries the inducing current is known as the primary, and the coil in which the current is induced, the secondary. The amount of electric energy in the two coils is equal, if we neglect the resistance of the wires and the energy required to magnetize the core, but, taking these into account, we get a much smaller amount in the secondary than in the primary. Therefore while we are able to increase our voltage to any required extent we must look for a corresponding decrease in the current.



INDUCTION COIL.

The change in voltage from the primary to the secondary is proportional to the number of turns in the two coils. If, for instance, the primary has ten turns and the secondary fifty, the voltage on the secondary should be five times that on the primary. By increasing the number of turns on the secondary in the proper ratio we could theoretically get any voltage desired, but practically there are limits beyond which it is not safe to go. The insulator on the secondary has to be looked after very carefully when we use high voltage, and the fineness of the wire used adds greatly to the cost and trouble of winding.

A small coil will be described, suitable for shocking, and a few of the experiments on high tension currents. Take a brass tube ten inches long and one inch in diameter, and slit it on one side the full length of the tube. This is to

prevent wasteful currents in it, which would greatly lower the efficiency of the apparatus. On each end of the tube slip a piece of fiber or vulcanite cut in the shape shown in Fig. 1. These pieces

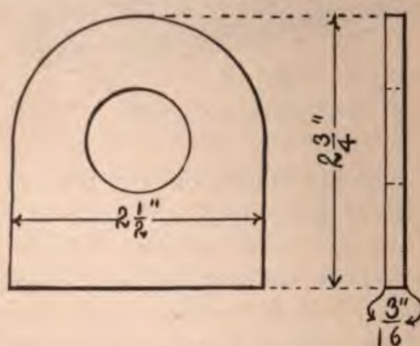


Fig. 1.

must fit on tightly. Carefully insulate the brass tube by winding several thicknesses of writing paper on it and shellacing them down, and drill a $\frac{1}{16}$ inch hole in one of the washers near the tube to let the starting wire through. The primary which is to be wound first is of No. 18 double cotton covered copper wire. Push about ten inches of the wire through the hole from the inside and wind in four layers, placing between each layer a piece of paper. The finishing end should be taken out through a hole in the washer,

where it stops. Shellac what you have wound on and cover it with six or eight thicknesses of writing paper well shellaced on.

For the secondary we will use No. 26 double cotton or silk covered copper wire. Make another hole in one of the washers for the beginning of the secondary to pass through. It would be well to use a larger wire to go out through the hole, say some of your No. 18, as the finer wire is likely to be broken off, which would necessitate unwinding the whole coil to repair it. So solder on a piece of the larger wire to your No. 26 and tape the joint well and push the larger wire through the hole and wind on as before. Shellac each layer as you finish it and cover it with a layer of paper. Wind the spool full. Now make a couple of little brass angles $2\frac{1}{2}$ inches long and a $\frac{1}{2}$ inch in each leg (see Fig. 2).

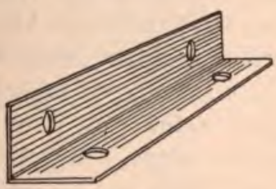


Fig. 2.

Drill them for screws and use them at the ends of the coil you have wound to screw it to a board you

have selected for a base. The core for our coil should be made of soft iron wires. These can be simply slipped inside the brass tube and left there permanently, or be made movable by attaching them to a handle. In the latter case a great variation in the secondary E. M. F. can be produced by sliding the core in and out. The wires should be rusty to avoid Foucault currents as far as possible. Cut the wire off in 10 inch lengths until you have enough to fill the tube snugly. Bind each end and the middle of the bundle with a few turns of fine brass wire and fit a wooden handle to one end.

A contact breaker must be provided to introduce into the primary circuit. This can be made by taking a piece of $\frac{1}{4}$ inch square wrought iron and bending it into a $\cup$ shape. The piece should be originally 4 inches long, and when bent make each leg 1 inch long. Wind the middle part $\frac{1}{2}$ inch deep with the same kind of wire you used on the primary, of course insulating the iron beforehand where the wire will touch it. A hole should be tapped in the end of one of the legs for $\frac{1}{8}$ inch machine screw. Cut a strip of sheet brass $\frac{1}{4}$ of an inch wide and $2\frac{1}{4}$ inches long for a spring for the vibrator. If the brass is not already springy enough, it can be made so by pounding it a little. Solder to one end of this

strip a piece of wrought iron such as you used for your magnet core, $\frac{1}{4}$ inch square and $\frac{1}{8}$ inch thick. Also, at the middle of the spring, on the opposite side to which you fastened the iron solder a small piece of sheet platinum for a contact. If platinum cannot be procured, silver is the next best thing. Through the other end of the spring drill an $\frac{1}{8}$ hole and screw it by this to the leg of the magnet you tapped, bringing the loaded end of the spring opposite the other leg.

Now fasten the magnet down to the baseboard of your coil by a cleat, so that the spring will be perpendicular and the loaded end in the air. The spring should be bent back as shown in Fig. 3, so

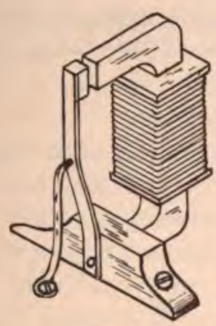


Fig. 3.

that the iron armature shall be about $\frac{3}{32}$ of an inch from the pole of the magnet. Now bend up a

piece of brass wire as shown in the same figure with a slotted eye in one end by which it can be screwed to the board and the other end of such a height that it will touch the platinum contact piece soldered to the spring. The end of the wire should also have a platinum contact soldered to it. Screw the wire down to the board so that its free end will just touch the spring and make a firm contact.

Four binding posts should be provided, two for the primary and two for the secondary. A diagram of the connections is given in Fig. 4. The

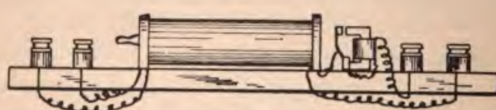


Fig. 4.

wires should be run underneath the baseboard in grooves cut in its bottom and carefully insulated from each other wherever they cross. The current is taken from one of the binding posts to one of the primary wires and from thence to the winding on the circuit breaker, then attached to the circuit breaker spring. The other binding post and the brass wire of the circuit breaker are connected. Each of the secondary wires is con-

nected to one of the other remaining binding posts. We are now ready to operate the machine.

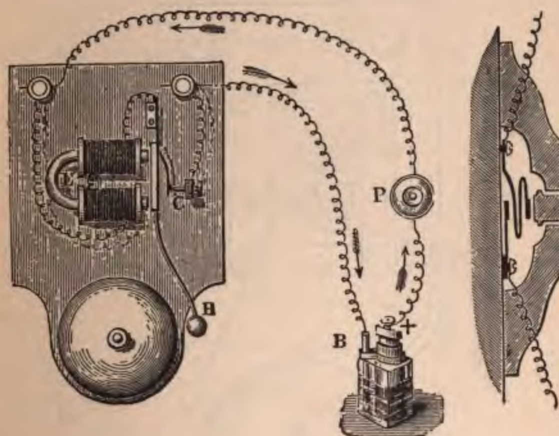
Connect two or three cells of the battery (the bichromate is the best for this purpose) to the primary binding posts. As soon as the current is turned on, the magnet of the circuit breaker should draw the iron on the spring to it and break the circuit between the spring and the brass wire. This of course allows the spring to fly back and again complete the circuit and then break it again, and thus keep up a steady vibration. The brass wire must be adjusted by means of the slot until the breaker works well and constantly. Now draw out the core of the coil and place your fingers on the two secondary binding posts and gradually push in the core when you will feel the well-known tingling of a pulsating current of electricity. When the core is pushed in the current becomes stronger and when it is pulled out the current weakens. By this method quite a range of electro-motive force can be secured. Of course the more batteries you use the stronger will be the secondary current.

CHAPTER V.

HOW TO MAKE AN ELECTRIC BELL.

THE common form of electric bell or trembler consists of an electro-magnet, which moves a hammer backward and forward by alternately attracting and releasing it, so that it beats against a bell. The arrangements of the instrument are shown in the diagram, in which E is the electro-magnet and H the hammer. A battery, consisting of one or two Leclanche cells placed at some convenient point of the circuit, provides a current when required. By touching the "push" P, the circuit is completed, and a current flows along the line and round the coils of the electro-magnet, which forthwith attracts a small piece of soft iron attached to the lever, which terminates in the hammer H. The lever is itself included in the circuit, the current entering it above and quitting it at C by a contact-breaker, consisting of a spring tipped with platinum resting against the platinum tip of a screw, from which a return wire passes back to the zinc pole of the battery. As soon as the lever is attracted forward the circuit is broken at C by the spring moving away from contact

with the screw; hence the current stops, and the electro-magnet ceases to attract the armature. The lever and hammer therefore fall back, again establishing contact at C, whereupon the hammer



is once more attracted forward, and so on. The push P is shown in section on the right. It usually consists of a cylindrical knob of ivory or porcelain capable of moving loosely through a hole in a circular support of porcelain or wood, and which, when pressed, forces a platinum-tipped spring against a metal pin, and so makes electrical contact between the two parts of the interrupted circuit.

Having briefly reviewed the principle and working of an electric bell, we will now proceed to construct a common $2\frac{1}{2}$ inch vibrating bell.

The base to which all the other parts are

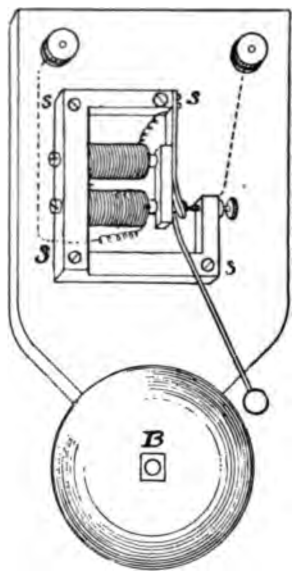


Fig. 1.

fastened, can be made of any hard wood, being careful that it is well seasoned. It should be about $\frac{3}{4}$ of an inch thick and 8 x 4 inches, shaped as shown in Fig. 1. Smooth the surface with fine

sand paper, then shellac and varnish it. To this attach the base plate, which can be made of cast iron (Fig. 2). Now you are ready to make the

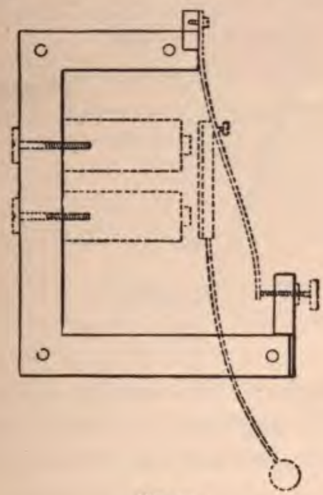


Fig. 2.

magnets. To do this, first take two 2 inch lengths of $\frac{5}{16}$ inch Swedish round iron, straighten them, smooth them in a lathe and reduce $\frac{1}{4}$ of an inch of one end of each to $\frac{3}{16}$ of an inch, leaving a sharp shoulder. Next take a 2 inch length of angle iron, drill in it two holes $1\frac{3}{8}$ inches apart, of the exact diameter of the turned ends of the cores, and rivet them securely in their places; this can

be done by fastening the cores in a vice whi
they are being riveted. Now bore two holes i
the other flange for the two screws which are t
hold the magnet to the base, see Fig. 3. Nov

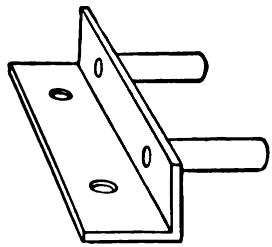


Fig. 3.

make the magnet cores soft by annealing. This is done by heating them to a bright red, then burying in hot ashes and allowing them to cool gradually. When the magnet cores and ashes are quite cold, which will be in from 12 to 24 hours, then the magnet may be taken out and its cores polished with a piece of emery cloth and the ends filed level and smooth. The base plate should also be annealed. The reason for annealing is simply this: we wish to make an electro-magnet, that is, a magnet that is a magnet only when a current of electricity is passing through its coils, and should the iron be hard it will retain a certain amount of

magnetism when there was no current passing, which would interfere with the working of the bell. The bobbins on which the wire is to be wound should be $1\frac{3}{4}$ inches long, and the heads about $\frac{1}{4}$ of an inch in diameter, and can be made of ebonite or any hard wood strong enough to allow of being turned down thin on the body so as to bring the wire as near the core as possible without touching it. Make the holes throughout the bobbins of a size to fit the iron cores exactly, and have the cores project $\frac{1}{8}$ of an inch above the end of the bobbins when these are fitted on.

Now wind the bobbins with No. 24 B. & S. cotton or silk insulated wire. Silk covered is the best, but cotton covered will answer for ordinary purposes. The wire must be wound on the bobbins from end to end regularly, with the coils side by side, as a spool of cotton is wound.

This may be done on a lathe, but a little practice will be necessary before the inexperienced hand can guide the wire in a regular manner. If, however, the spool of wire has a metal rod passed up its centre, and this be held in the hand at a distance of a foot or more from the bobbin on the lathe, the wire will almost guide itself on, providing the guiding hand be allowed to follow its course. With a little care, the wire for these

little magnets may be wound entirely by hand. Before commencing to wind on the bobbins, just measure off 8 inches of the wire (not cutting it off) and coil this length around a pencil, to form a small coil or helix. The pencil may then be withdrawn from the helix thus formed, which serves to connect the wire with one of the points of contact.

This free end is to be fastened outside the bobbin by a nick in the head; or the $\frac{1}{8}$ inch length, before being formed into a helix, may be pushed through a small hole made on the head of the bobbin, so that 8 inches project outside the bobbin, which projecting piece may be coiled into a helix as above described. The wire should now be wound exactly as a reel of cotton is wound, in close coils from end to end, and then back again, until three layers of wire have been laid on, so that the coiling finishes at the opposite end to that at which it began. To prevent this uncoiling, it should be fastened by tying down tightly with a turn or two of strong silk. The wire should now be cut from the hank, leaving about 2 inches of free wire projecting at the finishing end of each bobbin.

When the bobbins have been wound, they may be slipped over the magnet cores. They should fit pretty tightly; if they do not, a roll of paper may be put round the magnet cores, to ensure

their not slipping when the bell is at work. The helix ends of the bobbins should stand uppermost, as shown in Fig. 4. A short length of the lower

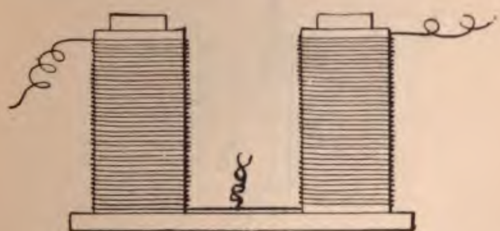


Fig. 4.

free ends of wire (near the base or yoke) should now be bared of their covering, cleaned with emery paper, twisted together tightly, soldered together, and any excess of wire cut off with a sharp pair of pliers. To prevent any chance electrical leakage between this bared portion of the wire and the iron, it should be carefully coated with a little melted gutta-percha, or covered with rubber tape.

The part that next claims our consideration is the armature, with its fittings. The armature is made out of $\frac{5}{16}$ square bar iron, of the best quality, soft and well annealed, and filed up smooth and true. The proportionate length is shown in Fig 5; and also the section of an

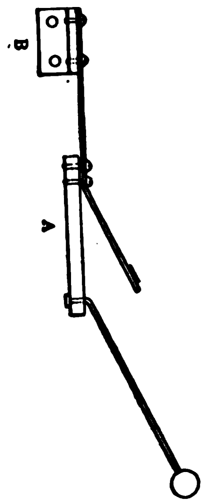


Fig. 5.

armature fitted with back spring and contact spring in one piece. This is cut out of hard sheet-brass, as wide as the armature, filed or hammered down to the desired degree of springiness, then filed up true on the edges. It may be attached to the iron of the armature, either by soldering or riveting. The spring at its shank may be screwed or riveted to the bracket. A short rod of stout hard brass wire is riveted or screwed into the freë end of the armature, and to the end of this rod is screwed or soldered the

metal bead, or ball, which forms the hammer or "ball" of the bell. The next portion to be made is the contact pillar, or bracket, with its screw, as shown in Fig. 6. This may either be a

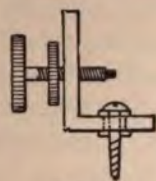


Fig. 6.

short stout pillar of $\frac{1}{4}$ inch brass rod, about 1 inch high, tapped on one side to receive the screw, which should be fitted with a check nut; or it may, as shown in the figure, be made out of a stout piece of angle brass. The exact size and length of the screw is immaterial; it must, however, be long enough to reach (when put in its place behind the contact spring) the spring itself, and still have a few threads behind the check nut to spare. The screw should be nicely fitted to the pillar, and the lock nut should clench it well, as when once the adjustment of the parts is found which gives good ringing, it is advisable that no motion should take place, lest the perfection of ringing be interfered with. Some makers use a "set screw" at the side of the pillar wherewith to hold the contact screw; others split the pillar and

spring it against the contact screw; but, all things considered, the check nut gives the greatest satisfaction. When the bell is in action, a tiny spark is produced at every make and break of contact between the contact spring and this screw. This spark soon corrodes the end of the screw and the back of the spring, if brass alone is used, as this latter rusts under the influence of the spark. To prevent this, a piece of platinum must be soldered or riveted to the spring, at the point where the screw touches, and also at the extremity of the contact screw itself. It is better to rivet the platinum than to solder it, as the platinum is very apt to absorb the solder, in which case it rusts quickly, and the goodness of the contact is soon spoiled, when the bell ceases to ring. To rivet the platinum piece on to the spring, it is only needful to procure a short length of No. 16 platinum wire, say $\frac{1}{8}$ of an inch, then, having drilled a corresponding hole at the desired spot in the contact spring, put the platinum wire half-way through the hole, and give it one or two sharp blows on an anvil, with a smooth (pened) hammer. This will at once rivet it in its place, and spread it sufficiently to make a good surface for contact

The screw must likewise be tipped with platinum, by having a small hole bored in the centre of its

extremity, of the same diameter as the platinum wire, which must then be pushed in and riveted by hammering the end, and burring the sides of the screw. Whichever method be adopted, care must be taken that the platinum tip on the screw and the speck on the contact spring are adjusted so as to touch exactly in their centres. It will be hardly worth while for the amateur to cast or even turn up his own bells (which are generally of the class known as clock gongs), as these can now be procured so cheaply already nickeled. The bell must be adjusted on its pillar, which is itself screwed into a hole in the base-board, where it is held by a nut. The adjustment of the bell is effected by placing it over the shoulder of the pillar, and then clenching it down by screwing over it a nut. The bell should clear the base, and should be at such a height as to be struck on its edge by the hammer attached to the armature (Fig. 5).

Having now all the parts at hand, we can proceed to fit them together, which is done as follows:—the bell pillar, with its bell attached, is fastened by its shank into the hole shown near B, Fig. 1, where it is screwed up tight by the square nut. In the same manner, we must fasten the contact pillar, or bracket. This being done, the

metal frame, Fig. 2, is put in position on the wooden base, as shown at Fig. 1, and screwed down thereto by the screws indicated at *s s s s*. The magnet may then be screwed down to the metal frame as shown. The small bracket of angle brass marked B, in Fig. 5, is next screwed into its place; that is, in such a position that the armature stands squarely facing the poles of the electro-magnet, but not quite touching them (say $\frac{1}{16}$ of an inch. In setting up this and the contact pillar, the greatest care must be taken that the platinum tip of the contact screw, Fig. 6, should touch lightly the centre of the platinum speck at the back of the spring (Fig. 5).

The free ends of the helically coiled electro-magnet wires should now be inserted into short lengths of small india rubber tubing, the extremities being drawn through and 1 inch of the copper wire bared of its covering for the purpose of making good metallic contact with the connections. One of these ends is to be soldered, or otherwise metallically connected, to the angle brass carrying the armature, spring and hammer, the other being similarly connected with the left-hand binding-screw, shown at Fig. 1. Another short length of wire (also enclosed in rubber tubing) must be arranged to connect the contact screw pillar with

the right hand binding screw. When this has been done, we may proceed to test the working of the bell by connecting up the binding screws with the wires proceeding from a freshly charged Leclanche cell. If all have been properly done, and the connections duly made, the armature should begin to vibrate at once, causing the hammer to strike the bell rapidly ; that is, provided the platinum tipped screw touches the platinum speck on the contact spring. Should this not be the case, the screw must be turned until the platinum tip touches the platinum speck. The armature will now begin to vibrate. It may be that the hammer runs too near the bell, so that it gives a harsh, dull buzz instead of a clear, ringing sound ; or, possibly, the hammer is "set" too far from the bell to strike it. In either case a little bending of the brass wire carrying the hammer (either from or towards the bell, as the case may dictate) will remedy the defect. It is also possible that the armature itself may have been set too near, or too far from the electro-magnet. In the latter case, the hammer will not vibrate strongly enough, in the former the vibration will be too short, and the armature may even stick to the poles of the electros, especially if these have not been carefully annealed. A

little bending of the spring, to or from the magnets, will remedy these deficiencies, unless the distance be very much too great, in which case the bending of the spring would take the platinum tip out of the centre of the platinum speck.

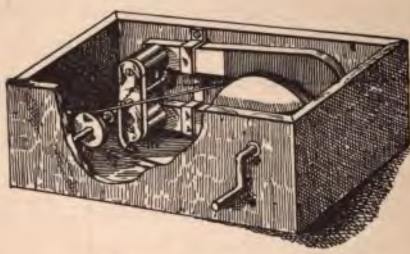
CHAPTER VI.

HOW TO MAKE A MAGNETO MACHINE.

THE "Magneto" is a dynamo with permanent field magnets. It is more suitable for use as a small dynamo than a self excited machine, for the reasons given in the chapter on the dynamo. The magneto at present finds its principal use in giving alternating currents for shocking or for ringing a bell. The same machine will do for either purpose. The first thing requisite is a horse-shoe magnet. This may be of almost any size, the larger the better, but one about ten inches long will be most suitable. A blacksmlth can make this for you if it is not convenient to buy one. The best tool steel should be used, or what is even better for our purposes, tungsten steel, which is susceptible of a much higher degree of magnetization. Bend up a piece a quarter of an inch thick and an inch wide, into a long U, or horse-shoe shape, leaving the opening between the ends an inch and a quarter. Temper this glass hard and magnetize it by the usual methods.

Make a box for the machine the length of the magnet plus half the distance between the

outsides of the ends, plus an inch long, and once and a half the distance the outsides of the ends wide and 4 inches deep. The armature of the machine is to be an electro-magnet with two spools. Measure the distance between the centre lines of the two legs of your permanent magnet at their ends and take a piece of wrought iron $\frac{5}{8}$ of an inch wide and $\frac{3}{16}$ of an inch thick, and drill two holes in it $\frac{3}{16}$ of an inch in diameter and the same



MAGNETO MACHINE.

distance between centres as was the distance between the centre lines you measured above. (The measurements given are about right for a 10 inch permanent magnet, and will have to be changed in proportion if the magnet is much larger or smaller than this.) This is called the yoke. Make the cores for the armature out of $\frac{3}{8}$ inch round

wrought iron, and in length three-quarters of the distance between the holes in the yoke.

Two cores will be needed. Tap one end of each for a $\frac{3}{16}$ inch machine, screw and fit on each core a fiber washer $\frac{1}{16}$ of an inch thick and $\frac{1}{4}$ of an inch less than half the distance between the yoke holes in external diameter. They must make a "driving" fit so they won't jar loose when the machine is set to running. (See Fig. 1.)

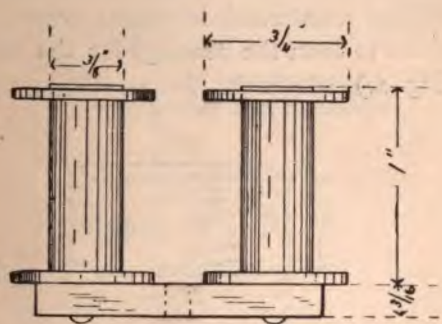


Fig. 1.

Insulate the spools thus formed with a thickness of paper around the iron part between the washers. The wire used in winding should be about No. 30 silk or cotton covered copper wire. Put the spools in a lathe and wind on the wire according to the

directions given in previous articles, taking the beginning end out through one of the washers. Bore a hole through the yoke, midway between the two holes already there, just large enough to make a driving fit on a piece of No. 24 Stubbs' steel which should be as long as the inside measurement of the breadth of your box. Take two pieces of brass of an inch thick, ½ of an inch wide and an inch long and through the middle of each bore a hole that will allow the piece of Stubbs' steel to revolve freely in it, yet not be loose, and through each end drill and countersink for wood screws. These brasses are to form the bearings for the armature. (See Fig. 2.)

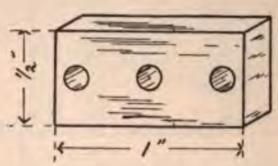


Fig. 2.

Put the permanent magnet in the box and fasten it by means of straps made of sheet brass to the side, making its centre line coincide with that of the side of box. Midway between the poles and ½ of an inch from the end, screw one of your brass

bearings to the box. Screw the bobbins you have wound to the yoke by means of the holes in the ends so as to form a U shaped electro-magnet.

Put that end of your Stubbs' steel armature shaft which is between the poles of your armature, into the bearing you have screwed on and drive the armature on the shaft until, when in position, the

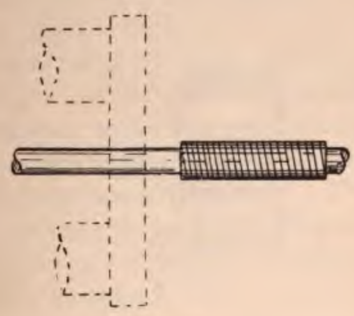


Fig. 3.

ends of the electro-magnet will be $\frac{1}{16}$ of an inch away from the poles of the permanent magnet opposite them. Remove your armature and on the yoke end of the shaft, close to the yoke, wind a strip of paper $\frac{3}{4}$ of an inch wide, shellacing it while winding it on, so that it will stick tightly. When this is dry take some bare copper wire anywhere

from No. 18 to No. 25, and wind it over this paper for nearly its full length tightly and compactly, and while it is yet tight run the soldering iron over it, putting on just enough solder to make the coil stick together when the winding tension is removed. This is to form the collector. (See Fig. 3.) It would of course be neater and better to use a small brass tube, if it can be had, instead of the wire.

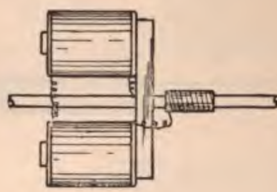


Fig. 4.

Connect up your armature as follows: Take a wire coming from one of the bobbins and connect it with that wire on the second bobbin which will cause the current to flow in the opposite direction around the two when you are looking at their ends; or, consider that your armature electro-magnet is straightened out instead of being U shaped, and then connect the bobbins in such a way that the current will go in the same direction around the mag-

net throughout its whole length. The other two ends are to be connected, one to the shaft of the armature and the other to the collector. (See Fig. 4.)

Now put the armature in place again in the box and screw on the other bearing so it will hold it there.

You will need two pulleys, one a small one to go on the armature shaft and another large one for the crank shaft. Brass is the best material to make them of, but hard wood will do. Make the one which goes on the armature shaft about $\frac{3}{4}$ of an inch in diameter with a sharp V shaped groove in it, and the one that goes on the crank shaft 4 inches in diameter and similarly grooved. Drill a hole in the centre of each that will make a good fit on the shafts, and, to insure their not turning, leave long enough hubs on them to put a set screw through.

For the crank shaft take a piece of $\frac{3}{16}$ in. wrought iron, leaving one end long enough to reach through the box from one side to the other; bend the rest into a crank of convenient length—say 2 inches, and with a 3 inch handle, as in Fig. 5. Cut out two more rectangles of $\frac{3}{16}$ inch sheet brass for bearings, for the crank shaft.

Make them $\frac{1}{2}$ of an inch by an inch and drill a $\frac{3}{16}$ inch hole in the middle of each for the shaft,

and a hole in each end for wood screws; screw these to the inside of the box so that when your crank shaft is resting in them it will be parallel to the armature shaft and as near the other end of the box as possible, and at the same time allow the pulley which goes on it to revolve freely.

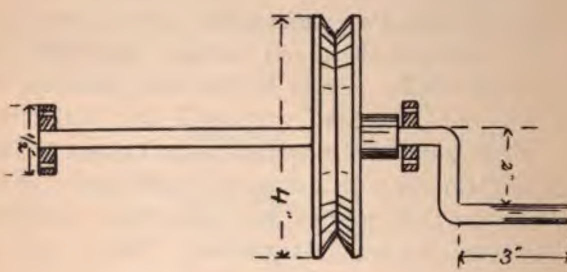


Fig. 5.

Put your pulley on so that its hub is turned towards the crank end of the shaft and after passing the shaft through the box until it rests in the opposite bearing and touches the wood beyond it (which must not be drilled through), adjust your pulley on the shaft until it touches the crank end bearing and screw the set screws tight. Your shaft will then have no end motion. Adjust the small pulley on the armature shaft until it is in line with the large one. For a belt, take a

round leather shoe string and pass it around the pulleys and cut it off so that the ends will lap an inch and a half when drawn up tight. Shave these ends off on a bevel so that they will fit each other, and then bind them tightly together with fine silk thread.

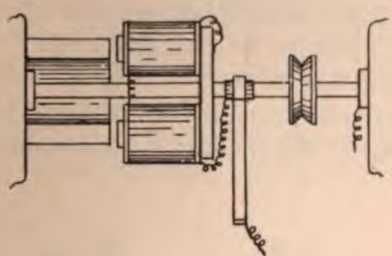


Fig. 6.

The collector brush is a piece of brass spring screwed to the bottom of the box and bent at right angles, so it will stand upright and press against the collector. Attach a wire to this spring and run it to the outside of the box, under a binding post. Solder another wire to one of the brass armature bearings and take that also outside and under another binding post. The machine is now ready to run. (See Fig. 6.) Run the belt on to the pulleys and turn the crank, and if everything has been properly made, you should get a

smart shock on putting your hands on the binding posts. The principal uses such a machine can be put to are "shocking" and ringing a bell.

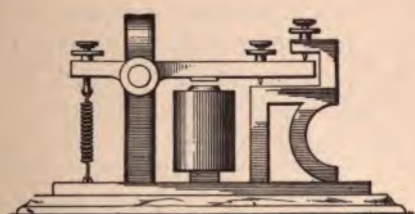
For the first, a couple of tin handles, such as are usually found on these machines, should be made and attached to the binding posts by flexible conductors. The bell-ringing can be done either with a "polarized" bell, or an ordinary electric bell rigged up so as to be "single stroke." To do this, run a piece of wire across the contacts in such a way that when the armature is drawn up by the magnet the circuit will not be broken.

CHAPTER VII.

HOW TO MAKE A TELEGRAPH INSTRUMENT.

THE most satisfactory way the author knows for an amateur to make a telegraph instrument is to saw wood, or apply himself to any other remunerative form of labor until he has made enough money and then buy himself one.

A cheap or poorly made instrument is a constant source of annoyance, and even the better



TELEGRAPH SOUNDER.

kind will occasionally take freaks. There exists, however, a class of people who take a much greater pleasure in anything home-made, and which they understand from beginning to end, than in the store article, even if the latter does look and work better; and it is to this class that I address my-

self, repeating my warning that they cannot expect to have a very pleasant time operating a home-made instrument. This instrument is one that cannot be "simplified" to any great extent without sacrificing its good qualities, so the form described will follow very closely that in general use at present.

The cores of the magnets are to be made of $\frac{3}{8}$ inch round wrought iron—Norway iron preferably, on account of its great purity and softness. Cut two pieces $1\frac{1}{2}$ inches long and tap one end of each for a $\frac{1}{8}$ inch machine screw. Fit over each end of each of them a washer made of fiber or ebonite 1 inch in external diameter and $\frac{1}{8}$ inch thick;—they must fit tightly. Insulate the cores between the washers and bore a $\frac{1}{16}$ inch hole in one washer on each spool to take out the beginning wire and then put the spools in a lathe and wind them full of No. 24 insulated wire according to the directions given in previous articles. It is customary to slip over the spool when the winding is finished a casing of ebonite both as a protection to the wire and to improve the appearance, but this is not essential.

The yoke is also soft iron $\frac{3}{8}$ of an inch wide, $\frac{3}{16}$ of an inch thick and $1\frac{1}{2}$ inches long. Drill a $\frac{1}{8}$ inch hole in each end, $1\frac{1}{4}$ inches distant from each

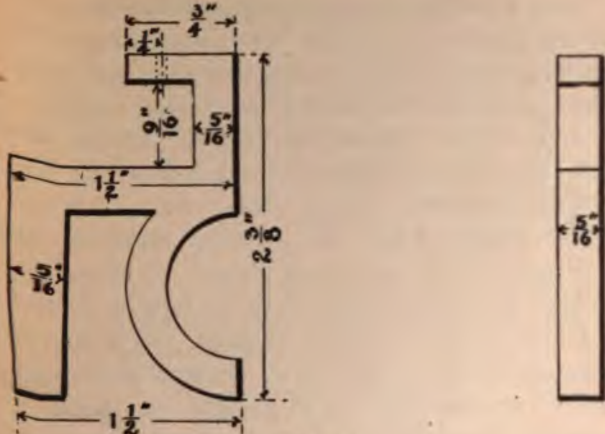


Fig. 1.

other and one in the middle tapped for a $\frac{3}{16}$ inch screw thread. Screw the spools you have wound to the yoke making a **U** shaped electro-magnet. This magnet stands on a base made of $\frac{1}{4}$ inch sheet brass, $2\frac{1}{4}$ inches wide and 5 inches long. Drill a $\frac{3}{16}$ inch hole through the base $2\frac{1}{4}$ inches from one end and midway between the sides: this hole is for the purpose of screwing the magnet to the base. Cut a strip of $\frac{1}{8}$ inch sheet brass $\frac{5}{16}$ of an inch wide and $10\frac{1}{8}$ long; bend it into a **U** shape, making the curved portion a semi-circle of 2 inches diameter; at 2 inches from each end drill and tap a hole for a $\frac{1}{2}$ inch screw.

Now file a groove in the edges of the two sides of the base-plate, $\frac{5}{16}$ of an inch in width, and $\frac{1}{8}$ of an inch deep, the edge of the groove to be $1\frac{3}{32}$ inches from the end of the plate the magnet is nearest. The legs of the U piece fit with this groove and are to be secured to the base with 8-32 machine screws.

The anvil had best be cast from brass, making a pattern for the same from Fig. 1. The bottoms of the legs of the anvil are to be tapped for 8-32 machine screws, and holes drilled in the brass base through which to pass the screws from underneath and secure the anvil. The straight leg should be 3 inches from the end of the base, and toward the magnet, as shown in the drawing of the completed instrument. The hole in the short arm is $\frac{1}{4}$ of an inch from the end, and is drilled and tapped for a $\frac{1}{8}$ inch screw.

Another brass piece which should be cast from brass, should be made in accordance with Fig. 2. The holes Y and Z are to be drilled and tapped for a $\frac{1}{8}$ inch screw, and X drilled with a No. 30 drill. Through the hole in the little downward projection of this piece is to be driven a piece of No. 14 Stubbs' steel wire, pointed at each end, and well hardened.

A soft iron armature of the shape and dimensions shown in C, Fig. 2, is screwed on the upper

side of the brass casting, to the hole Y. Four thumb screws and check nuts will be required, and may be made by following the dimensions given at B, Fig. 2. Two of the thumb screws should have their ends slightly countersunk or drilled with a very fine drill, to form bearings for the pointed ends of the Stubbs' steel pivot. Two more screws and nuts are needed: the screw to be made

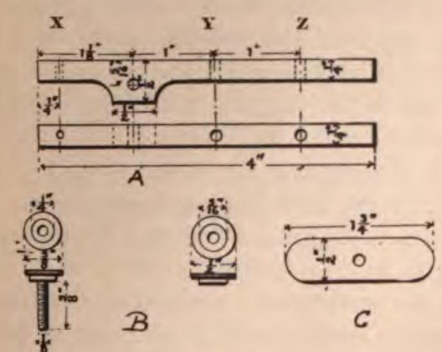


Fig. 2.

from $\frac{1}{8}$ inch brass wire, 1 inch long, and threaded the entire length, and the nut to fit this thread. Through one end of this screw drill a small hole. At $\frac{3}{8}$ of an inch from the end of the base plate, and directly under the projecting end of the armature carrier, back of the pivot, solder a small hook. Make a closed spring out of No. 22 spring brass

wire. We are now ready to put things together.

In the first place, the brass base-plate should be mounted on a neat wooden base, a little larger than the brass plate, and on the wooden base place two binding posts. Screw the magnet to the base-plate, if you have wound both cores in the same direction and have screwed them to the yoke so that both starting ends are together, connect the two inside wires together and the remaining ends to the binding posts, or, in other words, see that the wires are connected in such a way that if the magnet were bent out straight, the current will pass around the bar in one direction throughout its whole length. Screw the anvil to the base-plate and put in the adjusting screws and nuts as shown in the general drawing.

Place the armature in position and adjust it so that it moves easily on the pivot point by means of the adjusting screws in the sides of the U shaped piece. Put the nuts on the piece of threaded wire you made and slip it into the hole in the end of the armature. The end with the hole in it should be down, and into the hole hook one end of the spring you wound, and cut off the other end so that it will reach the hook beneath with a little stretching, and hook it there. The tension on the spring can then be regulated by the nuts on top,

and should be such that the armature will be pulled against the top stop when freed.

Adjust the screws in the anvil so that the armature will have $\frac{1}{8}$ of an inch play between them, and at its lowest point the soft iron piece will be $\frac{1}{32}$ of an inch from the ends of the magnet, and your sounder will be ready for work, that is to say, whenever you put a current through the coils the armature will draw down and make a click, and when the current is taken off, will fly up and make another.

The place in which the instrument is set makes a good deal of difference in the sound. A sounding board of some sort is necessary if it is desired to have the instrument make much noise. A good table answers for this very well, and often the instrument is placed upon a plate of glass or has a bell or a curved piece of tin attached to the anvil for the purpose of increasing the volume of sound. The Morse Alphabet is given below :

a	b	c	d	e	f	g	h
· —	— · · ·	· · ·	— · ·	·	· — ·	— — ·	· · · ·

i	j	k	l	m	n	o
· ·	— · — ·	— · —	——	— —	— ·	· ·

p	q	r	s	t	u	v	w
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x	y	z	&	.	?
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,	1	2	3	4
· — · —	· — — ·	· · — · ·	· · · — ·	· · · · —

5	6	7	8	9	10
— — —	· · · · · ·	— — · ·	— · · · ·	— · · —	——

To break and make the circuit and thus work the instrument, we must have a key which can be made from a piece of spring brass, as shown in Fig. 3.

TELEGRAPH KEY.

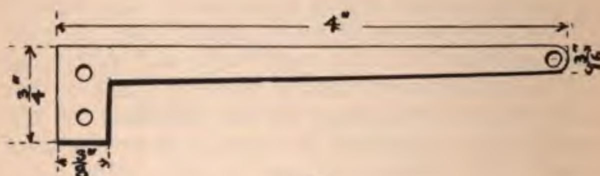


Fig. 3.

Cut and bend the brass in the shape shown, and screw a wooden or ebonite button to it. The screw head on the under side is to be filed off a little flat and another screw placed beneath, so that its head may be touched by the other when it is pressed down. The wires are to be connected to the strip and screw head as shown, though of course this is to be done underneath the board on which they are mounted, so that the wires will not

be seen. The circuit must be kept closed except when a message is being sent, so another strip of brass is to be screwed to the first, so it will move freely and will close the circuit when swung against the lower contact. A suitable handle is to be made for this.

The contacts of the key are apt to become fouled by the dirt and sparking on breaking the circuit, and must be occasionally cleaned. The fouling from the last cause can be obviated somewhat by soldering small pieces of platinum to the contacts as it does not oxydize as readily as most other metals.

CHAPTER VIII.

HOW TO MAKE AN ELECTRIC MOTOR.

THE fields of this machine are to be made of 4-inch wrought iron pipe. Take a piece 6 inches long and cut an opening $1\frac{1}{4}$ inches wide the length of the pipe. Insulate the iron with paper to within an inch of the slot and wind on the insulated part six layers of No. 18 cotton covered copper wire.

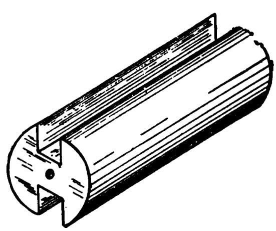


Fig. 1.

The armature core (see Fig. 1) is to be made of a round iron bar 6 inches long and $1\frac{1}{8}$ inches in diameter. Drill a $\frac{1}{8}$ inch hole from end to end through the centre of the piece and cut two slots in the opposite sides the full length of

the bars. The slots are to be $\frac{5}{8}$ of an inch wide and $\frac{3}{8}$ deep from the circumference, or in other words, the metal between the slots should be $\frac{3}{8}$ of an inch thick. Drive through the hole you drilled through the centre a steel rod which shall fit in it tightly and project $1\frac{1}{4}$ inches from one end and 1 inch from the other. Carefully insulate the inside of the slot and the ends of the armature core and the armature shaft for $\frac{1}{2}$ an inch from the core at each end.

The wire used is the same that you used for the fields. Leave a free end about 2 inches long and wind the wire in the slots in layers like a shuttle.

Fig. 2.

To tell how high to wind the wire, cut a hole in a piece of card-board $1\frac{1}{8}$ inches in diameter and slip it over the armature from time to time as the winding nears completion, and wind the wire so that it will nearly fill this hole. Secure the last wire as has been described before, and leave two inches free.

The commutator (Fig. 2) is to be made after the same plan as that used in the dynamo, with the ex-

ception that there are only two segments instead of ten. Cut out a circular piece of ebonite, fiber or hard wood $\frac{3}{4}$ of an inch in diameter and $\frac{3}{16}$ of an inch thick. Screw a brass washer to this of the same external diameter and $\frac{1}{4}$ of an inch inside diameter. Slot it as shown in the drawing and drill a $\frac{1}{8}$ inch hole through the ebonite for the armature shaft, and slip it on the end which projected $1\frac{1}{4}$ inches from the core. It should fit tightly and be pressed up against the winding, the segments facing outwards. Take the two free ends of the armature wire and after cutting them off the right length, solder one to the edge of each of the segments. From some $\frac{1}{8}$ inch sheet brass cut two pieces like those shown in Fig. 3. They are

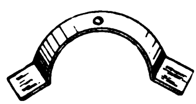


Fig. 3.

to be $\frac{1}{4}$ of an inch wide and bent so that when the armature is in position between the pole pieces of the fields and the shaft through the holes in the middle of these brass pieces their ends will rest flat against the poles and can be screwed to them. The piece at the commutator end of the shaft

must be bent out enough so that there will be about $\frac{1}{2}$ of an inch clear space between it and the commutator. At the other end it need only clear the end of the winding by the thickness of a washer, which you must place there to keep the wire from rubbing. The wire must be carefully insu lated from the washer by cloth and shellac. A small grooved pulley should be placed upon the end of the shaft opposite to that on which the commutator is.

After putting the armature in place in the fields the whole should be fitted to a base board, as shown, holes being tapped in the pole pieces by which it can be screwed to the board. Make the brushes of two pieces of spring brass and fasten them as shown in the drawing, where for sake of clearness the armature support is removed. (See Fig. 4.) You will need two binding posts on the base board of the machine. To one of them connect one end of the field winding ; the other end of the field winding is to be connected to one of the brushes and the other brush must be connected to the other binding post.

We are now ready to start up. See that the brushes press firmly against the commutator. Their ends should be bent slightly out so that they may not catch in the slots, and the points of con-

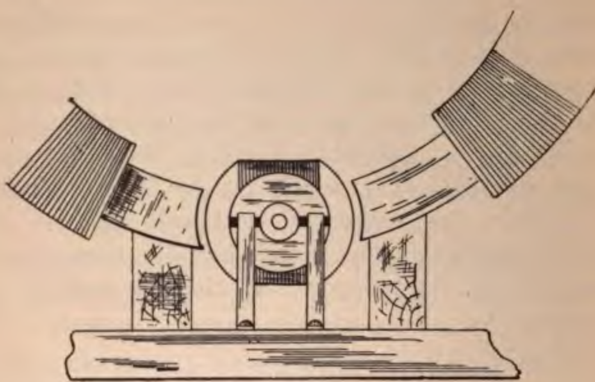
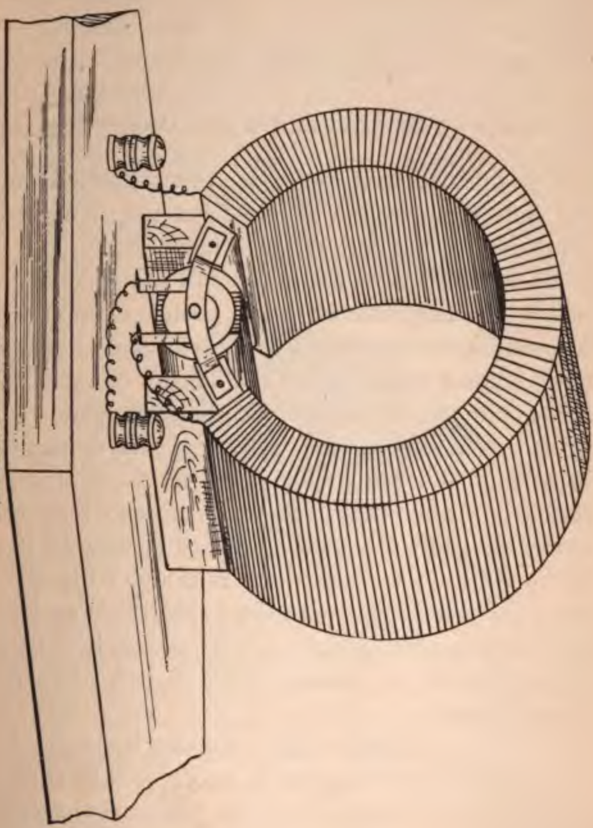


Fig. 4.

tact on the commutator should be diametrically opposite. Connect your source of current to the binding posts, and if every thing is properly made the armature should commence to revolve.

Three or four Bichromate Cells should run this at a pretty good speed, and it ought to give enough power to run a fan or any other small piece of machinery. It will not do to run it too slowly if you have a large electro-motive force, as it is likely to burn out.



MOTOR COMPLETE.

CHAPTER IX.

HOW TO MAKE A DYNAMO.

THE dynamo and motor are theoretically identical, but in practice a slight difference is made in the design, especially of small machines.

This difference is mainly due to the necessity of having the magnetic circuit or path for the lines of magnetic force as perfect as possible in a dynamo, since it must itself supply the energy to excite the fields, and the strength of the fields regulates to a great extent the amount of energy the dynamo is capable of delivering. With the motor, this is different, for while it is necessary that the magnetic circuit be good, if a high efficiency is desired it is by no means necessary to the running of the motor since the energy to excite the fields is taken from an outside source, which, it is supposed, is capable of meeting all the demands which will ordinarily be made upon it.

It follows, therefore, that in order to have a dynamo capable of doing much, we must have perfect fitting joints between the iron parts of the fields and as little charcoal as possible between armature and pole pieces, and all this means good workman-

ship with good tools. We would, therefore, advise the amateur who does not possess these latter essentials, to have the lathe work and planing done in some machine shop, as there is not much of it to do, and the dynamo will work in a much more satisfactory manner than if the machine work is botched.

The shaft of our armature should be made of machine steel ½ inch in diameter and 9½ inches long.

Fig. 1.

The core of the armature is made of disks of sheet iron 3 inches in diameter and punched out at the centre just large enough to fit tightly on the shaft. If these disks are made of ordinary sheet iron the black oxide on the surface is enough to insulate them from each other. They can, however, be made of tin plate, in which case it will be necessary to place pieces of thin tissue paper between them. (See Fig. 1.)

Drill a ⁹ inch hole through the shaft $3\frac{1}{8}$ inches trom one end, and another 3 inches from this hole. Place a piece of $\frac{1}{16}$ inch wire 1 inch long, through one of the holes, and then put the disks upon the shaft, driving them tight against the wire, and when you have put on enough to make a compact cylinder 3 inches long, drive a piece of wire through the other hole to keep the disks in place. The core must now be insulated by covering it smoothly with two thicknesses of heavy brown paper, stuck on with shellac. The armature shaft, also, should be treated this way for an inch and a quarter from each end of the core. Be careful to cover up every

Fig. 2.

part of the core, as it will be the source of much annoyance if a contact developes between it and the wire.

Divide the circumference of each end of the core into ten equal parts, being careful to have the divisions at one end exactly opposite to those at the other. At each division mark, saw a

slot ½ inch deep across the corner. Into each of these slots, drive a piece of stiff card-board or ebonite, as shown, leaving it to project about a quarter of an inch, and trimming it off even with the wire after the armature is wound, as in Fig. 2.

We are now ready for winding, and for this purpose will need about 2½ or 3 lbs. No. 18 double cotton covered copper wire. The winding we shall adopt is called the Siemens winding.

Begin at the end where the shaft is shortest and wind on the wire lengthwise on the core. The wire must be wound smoothly and tightly, but must be bent aside at the ends to allow for the displacement of the shaft. Be careful not to injure the insulation on the wire. Each coil if packed tightly should have 17 or 18 turns. (See Fig. 3.)

As soon as one coil is completed do not cut the wire but simply leave a loop two or three inches long and begin winding the next coil in the same direction. Begin the winding of each coil on the right-hand side of the division, and wind to the left, and begin the next coil where you leave off on the last. Give the loop a twist close to the core to prevent the first few turns of the wire on the new coil from getting loose. Before beginning a new coil, cover the last one at the ends of the armature where it will be crossed by the new coil with a piece of cotton cloth laid on with thin shel-

lac. When you have wound on five coils you will have occupied each of the divisions. Give the wire you have wound on, a good coat of thin shellac and cover it with a piece of cotton cloth. Now continue and wind over these coils five more in the same way, observing the same precautions, and when you have finished, cut off the wire and twist the end with the free end of the first coil. Shellac he last winding thoroughly.

Fig. 3.

Our dynamo is intended to run at a pretty high speed, so to prevent the wires flying out by cen-

trifugal force and rubbing against the pole pieces, we bind them down by a half a dozen turns of thin brass wire at a third of the length of the armature from each end. In order that the brass wire may not cut through the insulation of the wire and short circuit it, we place two thicknesses of heavy brown paper where the binding is to be, and if mica is obtainable a thin layer of that, too, and then wind the brass wire on tightly, a dozen turns at each end will do, soldering the wires together every inch or so.

Next in order is the commutator. The backing should be made of vulcanite or fiber, but if this is not obtainable, a piece of good hard wood, not liable to crack or shrink, can be made to do. If wood, it should be well paraffined.

Fig. 4 gives the dimensions of the commutator complete. If the brass hub be knurled where it goes through the vulcanite, it will keep it from slipping. A $\frac{1}{8}$ inch machine screw through the brass hub will keep it from slipping on the shaft.

The commutator bars are made from a ring of brass, which is first screwed to the vulcanite backing

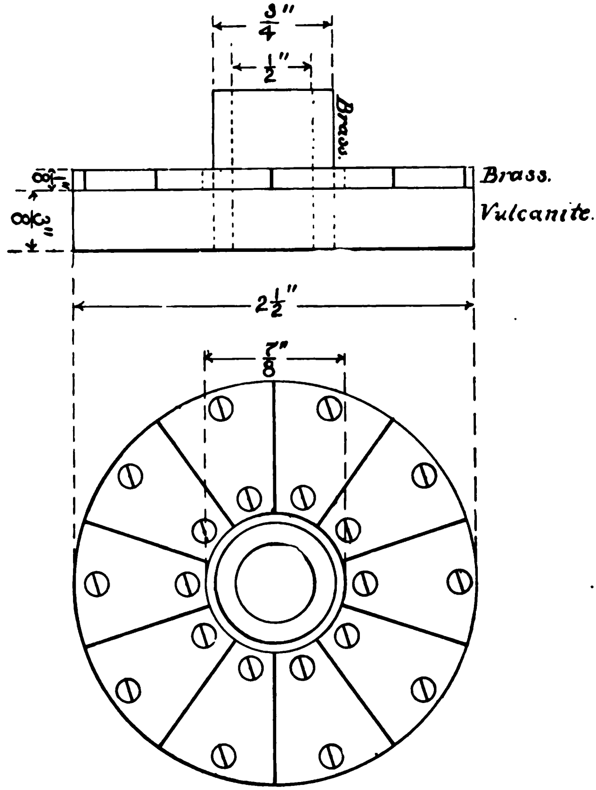


Fig. 4.

by twenty screws, the heads of which are countersunk just level with the surface of the brass. The ring is then cut radially into ten equal parts, while it is still screwed down. Put the commutator on that end of the shaft where the ends of the coils are left sticking out, and placing it with its end $\frac{7}{8}$ of an inch from the end of the shaft, and the segments of the commutator opposite the loops of wire, and set the set-screw; now pull one of the loops over the middle of the end of the bar opposite to it and cut it off so that it just reaches past the bar. Bare the ends of the wire and solder them together to the end of the bar. Do this with each loop, and your armature is complete except balancing.

To do this place two straight edges in a horizontal position, levelling them carefully, and placing them at such a distance apart that the ends of the armature shaft will rest upon them. If it tends to roll to any one position it needs some more weight on the top side of the position where it comes to rest. Put on a little solder and repeat the operation until it will stay in any position on the straight edges.

The dimensions of the iron parts of the fields are given in Fig. 5.

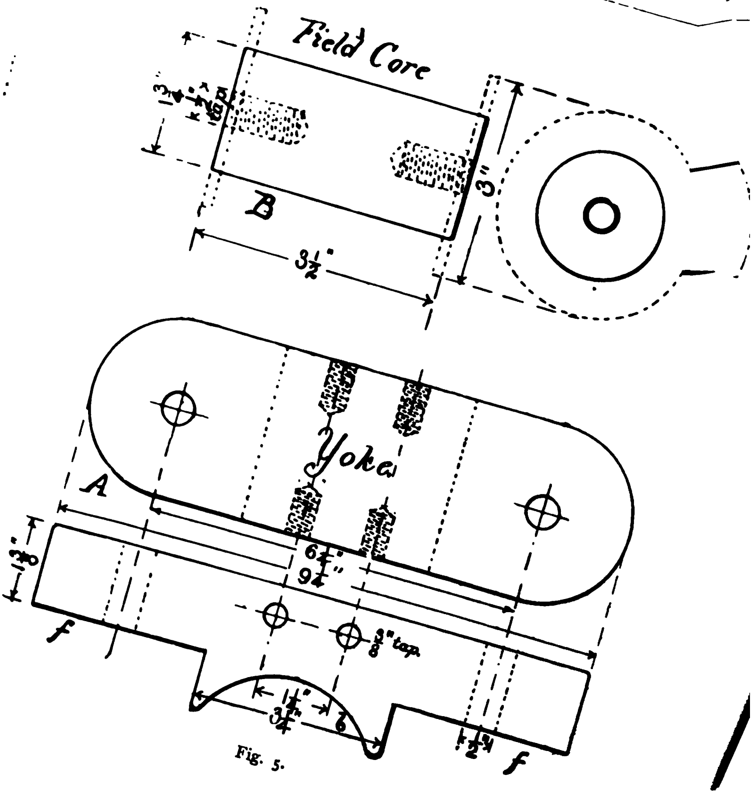


Fig. 5.

The pole pieces *A* could be cast iron, but the shape is so simple that they can easily be planed up from a slab of wrought iron, and will give much better results. The field cores *B* are simply pieces of wrought iron turned to size and tapped for half-inch bolts. The faces *f f* of the pole pieces and the ends *e e* of the field cores which are to join them must be accurately surfaced. The diameter of the bore *b* was intentionally omitted since no two inexperienced persons will wind an armature alike and it would be impossible to predict exactly its diameter when finished, and as the bore must be just large enough to allow the armature to revolve and clear. The diameter of the bore can best be found by calipering the armature.

The field cores must have washers of some sort, preferably fiber, to hold on the wire. They should drive lightly on to the core and have an external diameter of 3 inches, and be $\frac{1}{8}$ of an inch thick. Put one of these washers on each end of the field cores letting the core project just a trifle, say $\frac{1}{32}$ or $_{64}$ of an inch. Insulate the core by wrapping two thicknesses of heavy brown paper around it between the washers. Bore a $\frac{1}{16}$ inch hole through a washer on each core, close to the core and through this from the inside put 6 inches of the wire with which you are going to wind your fields. Bend it where it comes through to hold it, and putting the core in a lathe start it to revolving and wind on the wire. Be careful that it is wound on closely and tightly. After winding on one layer wrap a piece of paper around it and wind the next layer over this.

Wind on ten layers of the same kind of wire you used for the armature. When you begin to wind on the next to the last layer, tie a piece of string to the first turn and let the ends hang out, and when you finish the last layer before cutting off the wire tie the last turn down with the string, and cut the wire about 6 inches from the tie. Wind both fields in the same direction, we will say begin at the left-hand end and wind on the wire with the lathe running backwards. The supports for the ends of the armature should be cast of brass or moderately hard gun metal,—under no circumstances of iron. The dimensions are given in Figures 6 and 7.

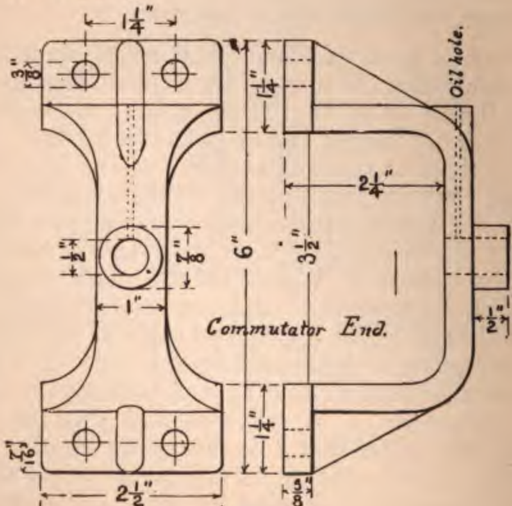


Fig. 6.

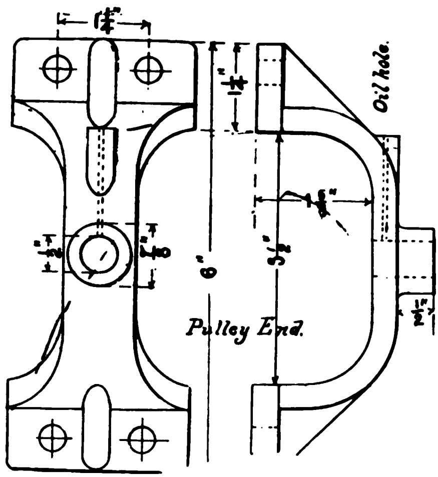


Fig. 7.

An oil hole should be bored in each bearing and an escape for the waste oil below, so that it may not get upon the pole pieces and thence to the armature.

The brushes and brush holder next demand our attention. The yoke had best be made of vulcanite or fibre, though good hard wood will do. The dimensions are given in Fig. 8.

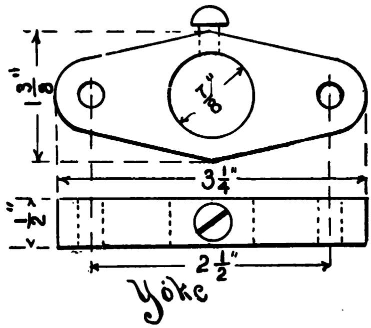


Fig. 8.

The brush holders are shown in shape and size in Fig. 9, and are to be made of brass.

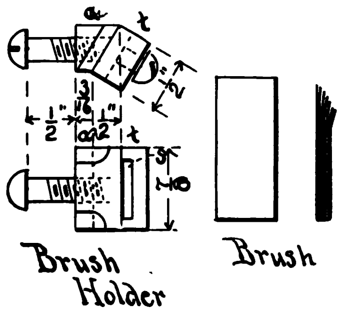


Fig. 9.

The piece *t* is soldered to the part *a* leaving the slot *s* through which the brushes are passed and held by the screw. The brushes themselves are

strips of thin copper $\frac{5}{8}$ of an inch wide and $1\frac{1}{2}$ inches long, three or four pieces going to make one brush, according to the thickness. They are soldered together at one end to keep them from slipping. The pulley is made of cast iron or brass, according to the dimensions given in Fig. 10. A collar to be placed between the armature winding, and bearing on the pulley end of the shaft, is made of iron $\frac{1}{4}$ of an inch thick and $\frac{3}{4}$ of a inch in diameter. and has a set screw to hold it to the shaft.

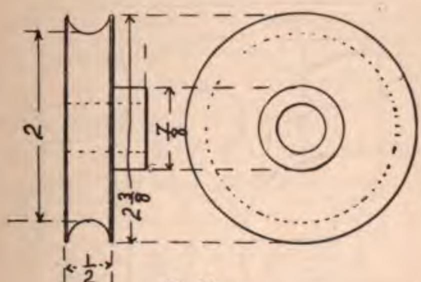


Fig. 10.

We are now ready to set up the dynamo. Bolt the bottom pole piece to the ends of the fields where the wires come out. Let the inside wires of the fields come out on what you have decided to make the commutator side of the dynamo, and cut grooves in the bottom pole piece for the wire to

lay in. The wire should, by the way, be tapped where it touches the iron. Bolt on the top pole piece and one of the bearings. Put the armature in position and bolt on the other bearing. A wooden base 9 in. × 10 in. × $1\frac{1}{4}$ inches should be provided and screwed to the bottom yoke of the fields. On this, place six binding posts, two for the armature cable and one for each of the ends on the field winding. A diagram of the connections is shown in Fig. 11.

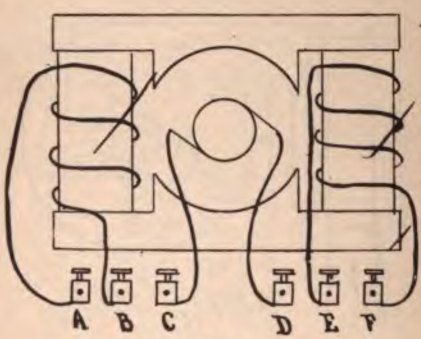


Fig. 11.

Binding post *A* is connected to the outside end of the left field, *B* to the inside end, *C* to the left-hand brush, *D* to the right-hand brush, *E* to the outside end of the right-hand field, *F* to the inside end. The brushes should be connected to the binding posts by means of flexible cables. One strand of

the twin conductor, such as is used to suspend incandescent lamps will do very well. The brushes should be set so that their ends bear firmly on the commutator. Turn the armature until one of the commutator slots is even with the end of one brush and set the brush so that its end is parallel with the slot. Then keeping the armature and brush yoke in the same position, set the other brush in the same way on the opposite slot. It is important that the brushes be set accurately, for if badly adjusted there will be sparking at the commutator, which will injure both brush and commutator.

Before starting up the machine, the fields must be magnetized. Connect the binding post *B* and *E* and put a current from a battery or other source of electric energy through the fields from *A* to *F*. Then remove the connection between *B* and *E*, and connect *B* to *C*, and *D* to *E*. Belt your dynamo to your source of power, and let it run at a high speed, the higher the better, within certain limits, say up to 2500 or 3000 revolutions a minute. If no other source of power is available, a sewing machine could be used by disconnecting the works from the fly-wheel and belting directly from that to the dynamo. The belt should only be tight enough to prevent slipping, as anything beyond this will waste energy in heating the bearings.

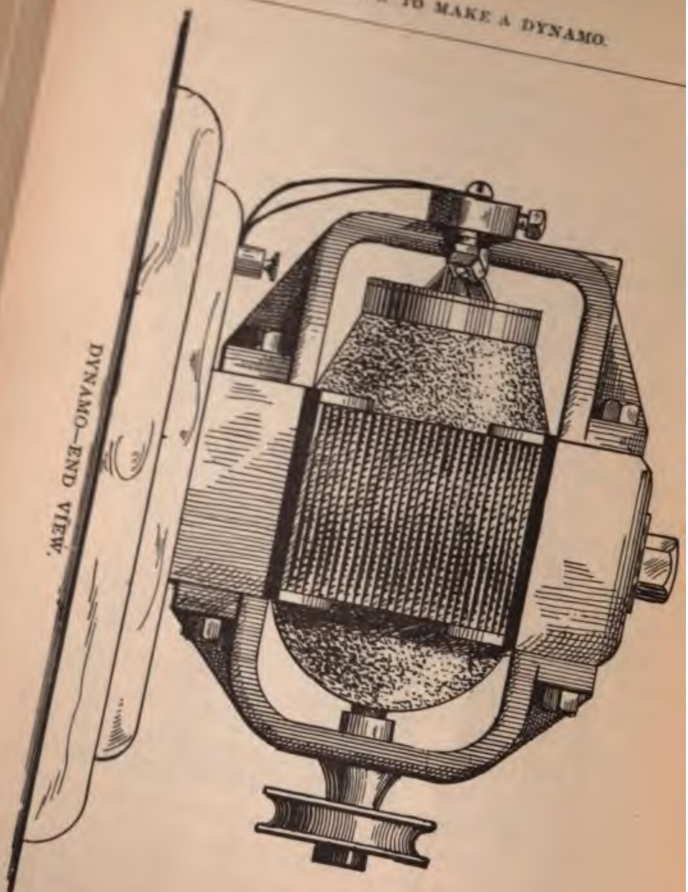
If you have a small steam engine the dynamo

DYNAMO—SIDE VIEW.

can be made to regulate, automatically, for a constant current, supposing your steam pressure can be kept constant. This is done by simply leaving off any governing device whatever from the engine and letting it run fast or slow, according to the demands of the dynamo. Of course nothing but the dynamo must be run from the engine. The dynamo must be run left-handed when you face the commutator. If the dynamo does not begin to generate immediately when the outside circuit from *A* to *F* is closed, gradually cut down its resistance until it does generate. Then shift the position of the brushes until there is no sparking at the commutator.

The method spoken of above for securing a constant current can be applied to running lamps in series. The lamps can be cut in or out of the circuit without changing the brilliancy of the rest, since the dynamo under the conditions given, is self-adjusting for constant current. It sometimes happens where a greater out-put from the dynamo is desired, that it is necessary to separately excite it. To do this, disconnect *B C* and *D E*, and connect *B E*. Connect the battery or whatever you intend to use to excite the fields to *A* and *F*.

The battery should be capable of sending three or four amperes through the fields. The external circuit is run from the terminals *C* and *D*. The



DYNAMO—END VIEW.

out-put can be nearly doubled by this method. This is, also, the method to use where constant potential is desired, but in this case, the speed must be kept constant, and engine or whatever supplies the energy, have some governing device. The current taken from the dynamo ought not to exceed five or six amperes. The circuit may go higher for short intervals, but it is not good practice to let it do so.

CHAPTER X.

ELECTRIC GAS LIGHTING AND BELL FITTING.

(Some practical directions for Amateurs.)

As Electric Gas Lighting and Bell Fitting has become a universal need, the following directions will not come amiss. Where a competent electrician can be employed it will be better to employ one, but in case it is impossible to do so, the amateur may, by following the directions here given, do a very good job.

Directions for Setting Up and Maintaining Batteries.

Crowfoot Gravity Battery.—Open out the copper, so as to present all of its surface to the action of the solution, place it in the bottom of the jar, run the insulated wire out of the top of the jar for connecting up. Suspend the zinc above the copper by hanging the hooked neck on the rim of the glass. The neck of the zinc is provided with a connecting clamp to receive the wire from the copper of the next cell. Pour clean soft water into the jar until it covers the zinc, then drop in six or eight ounces of copper sulphate (blue vitriol) in

small crystals. Connect the battery (for ordinary purposes) zinc of one cell to copper of the next and so on, and connect the two electrodes of the series and let them so remain for a few hours, until the separation of the two solutions, which will be known by the blue observed in the bottom of copper solution. This "blue line" should be maintained midway between the zinc and copper; when it is too low, drop in a few crystals of copper sulphate, when too high, connect the battery in short circuit as before described until it goes down. While the battery remains in action there is an increase in quantity of zinc sulphate solution in the upper part of the jar. The specific gravity of this solution should be maintained at 25°; when the hydrometer indicates a lower degree there is too little zinc sulphate solution, when a higher degree than 25° there is too much zinc sulphate, and a portion of it must be taken out, and that remaining diluted with pure water. When zinc oxide forms on the surface of the zinc, it must be taken out and washed in clean water with a brush.

Daniell Battery.—Fill the jar and porous cell with water and the pocket with copper sulphate. The directions for Gravity Battery will apply to the maintenance of the Daniell.

Samson Battery.—Directions for setting up and using.—Put six ounces of Sal-Ammoniac in glass jar, fill one-third full of warm water, and stir well. Clean, soft water is preferable. Use no more Sal-Ammoniac than will readily dissolve.

Insert the Carbon Vase and Cylindrical Zinc, taking care that Carbon is insulated from Zinc by cover and rubber band. See that cover fits down over the Carbon into its place in neck of jar; only one rubber band is required, say an inch from bottom of Carbon. When the Battery is set up, the solution should not quite reach the lower line of paraffine around neck of jar.

The Battery should be put in a cool, dry place. See that connections are clean and firmly made, and that the connecting wires are properly insulated.

When you add Sal-Ammoniac or water to make good any loss by evaporation, take out both Carbon and Zinc, and keep top of jar dry. It is better not to add Sal-Ammoniac to an old solution, but rather to use a little water and stir well.

When the Battery fails to work properly, throw out the solution, clean Carbon, Zinc and connections; let the Carbon stand in a warm place until old solution leaks out—if possible let it dry through—then set up the Battery with fresh solution.

When exhausted from over work or repeated grounds, clean the Carbon, let it

soak half an hour in hot water, give it a day or two of rest in the sun or other warm place, and it will again show up its full strength.

Leclanché Battery.—Directions for setting up.—Put six ounces of Sal-Ammoniac in the glass jar, add water enough to fill the jar about one-third full, stir this until it dissolves, pour a little of this solution into the porous cup, put the cup and zinc into the jar, and connect the battery as usual.

Grenet Battery, to make Solution.—To three pints of cold water, add five fluid ounces of sulphuric acid; when this becomes cold, add six ounces (or as much as the solution will dissolve) of finely pulverized bichromate of potash. Mix well.

To Charge the Battery.—Pour the above solution into the glass cell until it nearly reaches the top of the spherical part; then draw up the zinc and place the element in the cell. The fluid should not quite reach the zinc when it is drawn up.

Carbon Battery.—Fill the glass jar with water; the porous cell with electropoion fluid. The height of the liquid in the jar and the porous cells should be about the same.

Directions for making "Electropoion" Fluid for Carbon Battery.—Mix one gallon sulphuric acid and three gallons of water. Then, in a separate vessel, dissolve six pounds of bichromate of potash in two gallons of boiling water, mixing the whole thoroughly together. When cold it is ready for use.

To Amalgamate Zincs.—This may be very well done by first immersing the zinc in a solution of dilute sulphuric acid and then in a bath of mercury. A brush or cloth may be used to rub them, so as to reach all points of the surface.

The Fuller Mercury Bichromate Battery.—Amalgamate the zinc and its copper rod in the usual way. Place the zinc in the porous cells and pour into the latter a tablespoonful of mercury. Fill the porous cell with water to within about two inches from the top. Place the porous cell and the carbon in their positions in the jar as shown in the cut of the battery. Then fill the jar to within two, or two and a half inches of the top, with a mixture of three parts of electropoion to two parts of water. The zinc should be lifted out occasionally and the sulphate washed off. Keep a supply of mercury in the porous cell so as to have the zinc always well amalgamated. If the battery does little work it will last three or four months without being

touched. To renew, clean all deposits from carbon and zinc, and set up with fresh solutions as above.

How to Put Up Automatic Gas Burners.

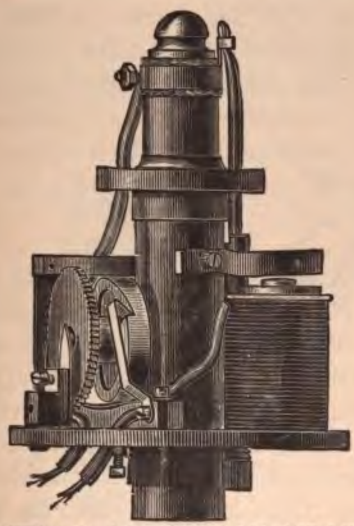
The battery to be used is some form of open circuit, preferably the Samson or Leclanché Disque. Place the battery, consisting of four or six cells, according to size of the house or number of burners to be used, in the cellar or lower hall-way, taking care to select a place of uniformly cool temperature. The place selected should not be too dry, for a dry atmosphere tends to evaporate the fluids too rapidly ; nor very damp, as too much moisture interferes with the action of the battery.

To Connect the Battery.—Connect the zinc of one cell with No. 16 or 18 wire to the nearest gas pipe on the house side of the gas meter. To make contact with the gas pipe perfect, file a bright surface on it and wind the bared copper wire around it several times. After the cells have been joined together, carbon of one to zinc of next, run a wire from the last carbon through a one-point switch, located near the battery, to the spark coil; then from the spark-coil make connection to the bunch of wires which lead to the various rooms of the house.

To Detect a Ground.—Disconnect the battery wire from the bunch of wires in the cellar and touch each house wire with it separately. The grounded wire will be detected by a spark and should then be left out of the bunch of wires, which may now be connected with the battery wire again. The fixtures to which the grounded wire runs should be carefully examined, as the trouble is most likely to be in the fixture wiring or where the connection is made back of the wall plate. If, however, the trouble is between the fixture and the cellar, a new wire should be run. After the trouble is removed connect the wire with the bunch of wires as before.

For Automatic Burners, run wires from the cellar (where connection is made to battery wire) to the centre brass strips on the rear of the key, or press-button plate. Run wires from the other points of the press-button plate to the automatic burner, which is to be governed from that point, and connect the wire from the black press-button to the electro-magnet which shuts off, and the wire from the white press-button to that which turns on the gas. The circuit for lighting is made from battery, through switch, spark-coil, wire, brass, strip on press-button plate, by pressing the white button, through the electro-magnet which turns on

the gas, wire at the tip of the burner (by the union and parting of these wires the igniting spark is made), thence to the gas pipe, and back to battery. For shutting off, the same circuit is made, except that by pressing the black button the circuit is closed through the other electro-magnet in the automatic, thus shutting off the gas.



THE S. M. AUTOMATIC GAS BURNER.

How the S. M. Automatic Operates.—By the touch of a press-button, an electric current from the battery is sent through the helix of the mag-

net, which vibrates the armature carrying the circuit-breaker. The armature having a pawl attached to its lever end, rotates the rachet-wheel connected to the spindle of the gas-cock to open the valve. When the rachet-wheel is turned two-thirds around and the gas ignited, the commutator shifts the current into another circuit, leaving the flame. The pressure of a second button again actuates the armature and forces the pawl to further rotate the rachet-wheel one-third around, to shut off the gas. The commutator automatically cuts out the electric current when the lighting or extinguishing is accomplished, which saves grounding the battery by continued pressure or imperfect connections at the press-button.

To Connect the same Automatic with more than one Key or Press-Button.—Run independent wires from the switch-board to each key and connect as before with the central brass strip. Run wires from each electro-magnet in the burner to the farthest key, and connect, as in a single key, the white button with the lighting, and the black with the shutting off wire. Run branch wires to the other keys, making *fast connections;* the wires from the white button connecting with the wire already run from the white button of the farthest key, and the black with the other wire.

To Light more than one Burner from the same Press-Button Plate.—Select the key with buttons corresponding to the work required, two buttons for a single burner, four for two burners, six for three, etc. Run a wire from the battery to the press-button and connect it with all the centre strips on the back of the plate. Run separate wires from the black and white press-buttons in the first set, and connect with burner No. 1, as with a single automatic; run a separate wire from both press-buttons in the second set and connect in the same manner with burner No. 2; and in the same way with all the other sets.

THE BOSTON RACHET BURNER.

The Boston Rachet Burner.—The first pull of the chain turns on the gas through a four way gas-cock governed by a rachet wheel and pawl. The issuing gas is lighted by a wipe-spark at the tip of the burner. Alternate pulls shut off the gas.

To Put Up The Hand-Lighter.

Run a single wire from the battery as with the Automatic, and connect it with the binding screw on the insulated collar at the tip of the burner. The movement of the pending chain brings the spring wire at the end of the movable arm into connection with the fixed electrode on the insulated collar, closing the electrical circuit, the subsequent breaking of which produces the igniting flash or spark.

General Directions.

Switches.—A switch near the battery is useful, so that in case of any trouble the occupants of the house can switch off the battery and save it from running down.

Spark-coil.—An eight or ten-inch spark-coil is sufficient for lighting coal-gas.

Connections.—Simply winding the wire is not sufficient to produce a perfect connection; soldering is necessary, and rosin, not acid, should be used.

Insulation.—Particular care should be exercised in every part of a job, that perfect insulation be obtained. Any leakage will rapidly destroy the efficiency of the battery. Every foot of the wire should be closely examined before being run, and all suspicious places wound with the rubber tape.

Running Wire in Damp Places.—Extra care should be taken in running wires through damp places. For walls and other equally bad sections, rubber-covered wire is good. Where tacks are used, the wire should be covered with rubber tape. Steam or hot water pipes should never be crossed, except that extra care be taken that the wires do not come in contact with them, as the heat melts the paraffine on the covering of the wire and destroys the insulation, often causing a ground.

Hints for Running Wires out of Sight.—From key or press-button plate on the wall to the floor. Punch a hole through the plastering at the required position, being careful that there is no studding at that place. Use a brad-awl, and cut the hole large enough to set in the press-button plate. With a few inches of small brass spring wire, push through the opening a few inches of No. 19 double jack-chain, such as is used for general fishing purposes, first having connected the end of the chain

with a piece of heavy linen thread. Run out the thread until the chain touches the floor beneath (between the laths and the outside wall); move the thread and locate the chain by sound. Bore a hole through the base-board or floor, as the case may be, towards the chain. Use a two or three-foot German twist gimlet. With a small brass spring wire, bent at the end in the shape of a hook, fish for the chain and draw it out. At the other end of the thread attach the wire and draw it through with the thread. Passing under the floor, bore a second hole through the floor as near the other as possible. Run into this a piece of snake or fishing wire (which is $\frac{1}{8} \times \frac{1}{64}$ inch steel wire, with a hook at the end), until it comes to an obstruction. Locate the obstruction by sound. In running wires under the flooring, first carefully examine all parts and find the direction in which the beams and timbers run, and run wires parallel with these. After locating the end of the fishing wire, see if the obstruction be a timber; if so, find the centre and bore from the middle diagonally through it in the direction of the fishing wire. Drop a jack-chain and thread through the hole; fish for it and draw it through hole No. 2, attach the insulated wire and draw it back. Starting at hole No. 3, bore hole No. 4 diagonally through the timber in the direction in which the wire is to be

run, making holes Nos. 3 and 4 form an inverted V through the timber. Run the fishing wire through hole No. 4, until it meets an obstuction. If at the end of the room, bore through the floor, drop chain, fish it out, attach wire, and draw it home. Putty up holes after having done with them; or in case of hard finish, plug them up with wood. In lightly built houses it is often found easier to take off the moulding above the base-board and run the wire under it. In such cases care should be taken to break off the old nails, as any attempt to drive them out would cause a bad break. In closets and around chimneys it is usually found easy to work. A mouse or lead weight attached to a string may often be dropped from the attic to the cellar ceiling through the space outside the chimney. It is well before starting on a job to carefully examine the whole house, and find the easiest places to run in. When necessary to take up carpets, be sure to put them down again as quickly as possible, in order to reduce to a minimum the inconvenience to residents.

Wiring Fixtures.

Where it is impossible to run the wire between the gas pipe and the outer shell, run it above if the fixtures be overhead; below if the fixtures be low down, and bind the wire close to the fixture with

fine thread, being sure that the sharp corners will not cut through the insulation and eventually cause aground. Shellac the wire to the pipe, and when hard, remove the thread. At the joints or hinges connect the nearest set points by means of a wire loop of sufficient size to in no way interfere with the action of the fixture, and wind the insulated wire around this loop in the form of a spiral. Great care should be taken that perfect insulation be obtained, and in all such parts the wire should be covered with rubber tape. In running wire between the gas pipe and the outside shell, the same care should be exercised to guard against grounding. To pass the rings and other sections where there is not sufficient space, bore through with a small monkey-drill, or punch a hole with the brad-awl, or file off sufficient metal to allow an exit; if necessary, run the wire through and over the obstruction. Rubber tape must be used wherever the wire passes near the metal of the fixture or is liable to touch it.

The Best Time to Wire a House is when the builders have finished boarding in and have not yet commenced lathing. The cost of wiring at that time is very much less, sometimes not more than one-half as much as in the finished structure. In houses already occupied, the inconvenience caused by putting in wires is slight. Little or no dirt need be made; there need be no hammering and pulling away plastering, laths and floors. The most expen-

sive finishing should in no way be injured by the workmen. When the job is complete, and well-done, it will be difficult to discover evidence of the work having been done.

Tools and Materials Necessary for Wiring a House.

Rubber Tape, for winding wire where tacks are driven for holding wire overhead—to insure perfect iusulation, and prevent breaking through because of sharp edges.

Tags, for numbering wires at the battery.

Double-pointed Tacks, for holding up wire. Use as few as possible.

Brass Spring Wire. A few inches for pushing chain through holes.

Steel Spring or Snake Wire, for fishing purposes. Fifty feet is sufficient.

No. 19 Double Jack Chain. A small amount for dropping purposes.

Common Brad Awls, for punching holes through walls, etc.

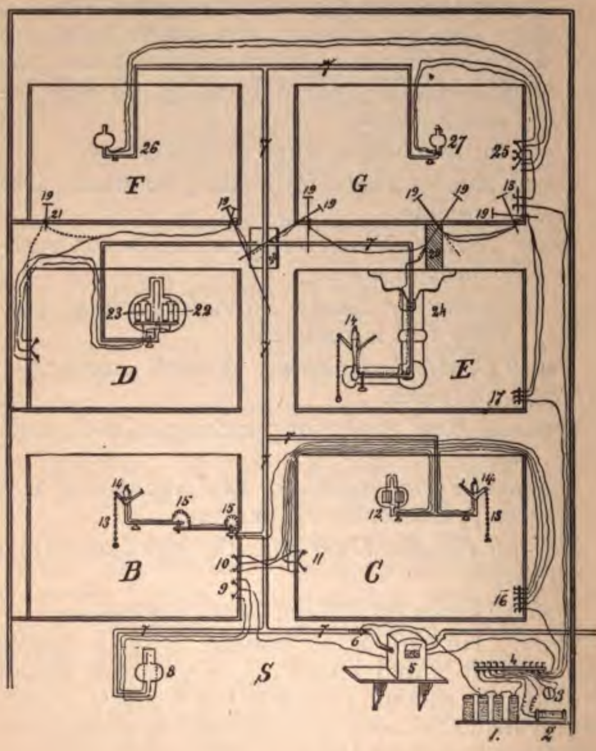
German Twist Gimlets, two and three feet long, $\frac{1}{4}$ or $\frac{5}{16}$ in., for boring purposes.

Rat-tail File, for filing holes through fixtures and other metal.

Monkey Drill, for drilling through metals.

Wire. No. 16 or 18 braided wire is heavy enough, if it is well insulated. Great care should be taken in examining the wire to see that it is thoroughly insulated, as more depends upon this than any other feature of the job. The larger the wire, the less the resistance.

The reader can form from the diagram on this page, and plan on opposite page, a very good idea of how to wire a house for Electric Gas Lighting.



Plan for Wiring a House.

1 Battery on Shelf.

2 Spark-oil.

3 Galvanometer.

4 Switch-board, with Individual Switches.

5 Gas-meter.

6 Connection of wire from battery with gas-pipe on house side of meter.

7 Gas-pipe.

8 Automatic in room S.

9 Press-button or key-plate for lighting No. 8.

10-11 Press-button for lighting No. Auto. No. 12.

13 Pendant Chain of Hand-Lighter.

15 Loop for passing wire around joint in fixture.

16 Switch for first floor.

17 Switch for second floor.

18 Switch for third floor.

19 Gimlet, showing direction of holes for running wires out of sight.

20 Beams, with wires run through them.

21 Showing manner of carrying wire around corner of room below, bringing it through hole and then dropping it back into position.

22 Part of Automatic, with Electro-magnet, showing the shut-off.

23 The same, showing the turning on and lighting.

24 Showing how to run wire between gas-pipe aud fancy covering of fixture.

25 Four press-button plate, lighting Nos. 26 and 27.

ELECTRIC BELL FITTING.

There are three principal forms of Vibrating Electric Bells. The wooden back, the iron back, and the iron box bell.

THE VICTOR BELL.

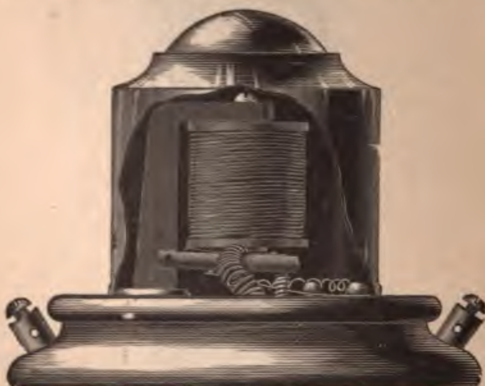
The Victor Wooden Box Bell.—Its superiority consists in a soft iron bed-plate, to protect the adjustment from warping of the base-board; a double adjustment of the tension of spring as well as length of stroke; a novel and convenient clasping device for fastening the box to the base-board; platinum contact points, and gongs of superior tone. The magnets of the 2½, 3 and 3½ inch bells are wound to three ohms resistance, and the gongs, binding posts, armature and hammer are all nickel plated. Finished in black walnut, plain and stained cherry, oak and ash boxes.

The "Victor Iron Back" Bell is the same as the "Victor," except that the soft iron bed-plate is made to answer the purpose of a back as well, thus doing away altogether with the wooden base-board. A finely finished wooden box is used, as with the "Victor" bell.

THE CLIMAX IRON BOX BELL.

The "Climax" Iron Box Bell is thoroughly well made with magnet and working parts entirely protected from dust, dampness, etc., by an iron box ingeniously fastened to the iron base. It has a double adjustment, and rings easily on one cell of Samson battery. For use in exposed places it has no equal.

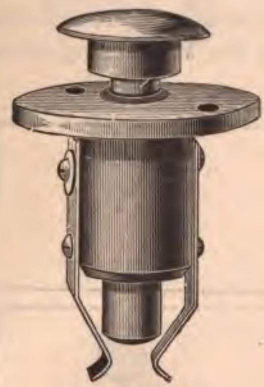
The "Boss" Electric Buzzer is designed for stores, offices, banks, etc., and is used to summon clerks or employes from their desks without attracting general attention to the call. The armature is pivoted to the base of an upright soft iron shield, from the top of which the magnet is firmly suspended. The armature, being pivoted to the shield vibrates between the magnet and wooden base and



THE BOSS ELECTRIC BUZZER.

is regulated by an adjusting screw underneath. It works free and easy on one cell of Battery; occupies very little space; has binding posts on the outer edge of the base; is thoroughly constructed, and attached to highly polished mahogany, black walnut, cherry or ash bases, while the mechanism is co[illegible]th a nickel-plated or polished brass s[illegible]

Improved Nickel-plated Floor Push.—The push is removable and has a shoulder to prevent the insulated body being pushed out in case it is stepped on. There is a hole clear through the body of the push, thus providing an escape for dust.



FLOOR PUSH.

Door Bell-pull Attachments.—Designed for connecting a mechanical door pull to ring an electric bell. It can be attached without displacing the bell-pull already in use, and may be arranged to operate both the mechanical and electrical bells.

DOOR PULL ATTACHMENT.

Fig. 1 shows the arrangement of a single battery supplying several bells, operated separately by different buttons, the bells being connected in multiple.

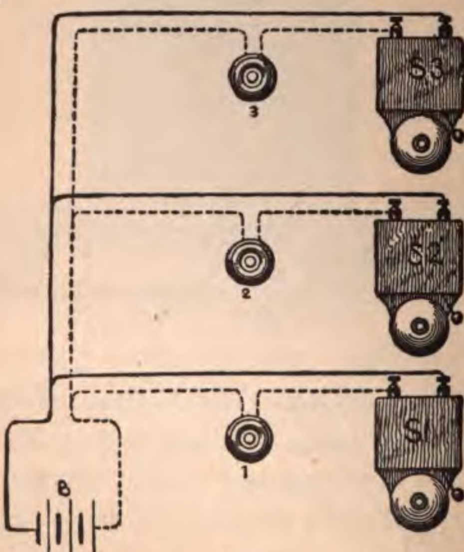


Fig. 1.

Fig. 2 represents a battery B, acting on a bell operated by three different buttons, 1, 2, 3.

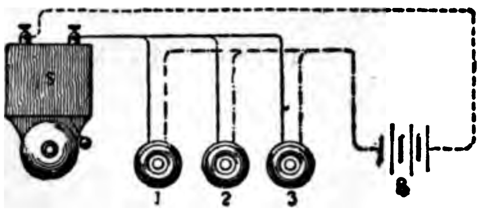


Fig. 2.

CHAPTER XI.

SOME INFORMATION IN REGARD TO ELECTRIC LAMPS.

The Voltaic Arc.—If two pointed pieces of carbon are joined by wires to the terminals of a powerful voltaic battery or other generator of electric currents, and are brought into contact for a moment and then drawn apart to a short distance, a kind of electric flame called the *voltaic arc* is produced between the points of carbon, and a brilliant light is emitted by the white hot points of the carbons.

Before contact, the difference in potential between the points is insufficient for the current to leap across the air-space, therefore the carbons must be made to touch one another before the current can be established.

On separating the carbons the momentary extra-current due to self-induction of the circuit, which possesses a high electro-motive force, can leap the short distance, and in doing so volatilises a small quantity of carbon between the points. Carbon vapour being a partial conductor, allows the current to continue to flow across the gap, provided it be not too wide; but as the carbon vapour

has a very high resistance it becomes intensely heated by the passage of the current, and the carbon points also grow hot. Since, however, solid

THE VOLTAIC ARC.

matter is a better radiator than gaseous matter, the carbon points emit far more light than the arc itself, though they are not so hot.

The upper or positive carbon is consumed about twice as rapidly as the lower or negative carbon; the lower one becoming pointed, while in the upper a crater is formed. With the alternating current both carbons are consumed at the same rate, and both retain the pointed form, which permits a free radiation of the light in every direction.

The globules on the surface of the carbons result from silicia, which is found in them as usually prepared, and in fusing collects on the surface of the carbons, as seen in the engraving.

The quantity of light emitted by an electric lamp is disproportionate to the strength of the current; and is, within certain limits, proportional to the square of the heat developed, or to the fourth power of the strength of the current.

The Arc Lamp now in general use consists simply of two hard carbon rods and a mechanical contrivance to feed them—that is, push them forward as fast as needed.

It is requisite that the mechanism should start the arc by causing the pencils to touch and then separate them to the requisite distance for the production of a steady arc; the mechanism should also cause the carbons not only to be fed into the arc as fast as they consume, but also to approach or recede automatically in case the arc becomes too

THE ARC LAMP.

long or too short; it should further bring the carbons together for an instant to start the arc again if by any chance the arc goes out.

There are a great many forms of arc lamps, but the one in general use by a number of the large companies is the clutch lamp. This is a simple device, and is that of employing a clutch to pick up the upper carbon holder, the lower carbon remaining fixed. In this kind of lamp the clutch is worked by an electro-magnet, through which the current passes. If the lamp goes out the magnet releases the clutch, and the upper carbon falls by its own weight and touches the lower carbon. Instantly the current starts round the electro-magnet, causing it to act on the clutch which grips the carbon-holder and raises it to the requisite distance. Should the arc grow too long the lessening attraction on the clutch permits the carbon-holder to advance a little.

The lamp in the illustration is one of the Brush Electric Co.'s make, and is a double-carbon lamp. When one carbon has burned out, the current is shifted automatically to the other, thus making the life of the lamp twice as long.

Incandescent Lamp.—The incandescent lamp consists of a glass globe or bulb, from which the air has been exhausted, containing a carbonized fibre of

bamboo. This carbonized fibre is attached to two platinum wires fused in the glass, the free ends of the wires being connected to the copper sockets of the lamp, which are insulated from each other by

THE INCANDESCENT LAMP.

plaster of paris. The wires are then connected to the external circuit. A 16-candle power lamp, with an E. M. F. of 110 volts, has a resistance of about 190 ohms. A lamp will only last a certain number

of hours in proportion to the intensity of the current sent through it; therefore it must be renewed as often as it burns out. The average life of a lamp is a little over one thousand hours. The incandescent lamp shown in the illustration is the ordinary form used in the Brush system. Ordinary lamps are about 16-candle power, although they are made from 1-2 to 150 candle power.

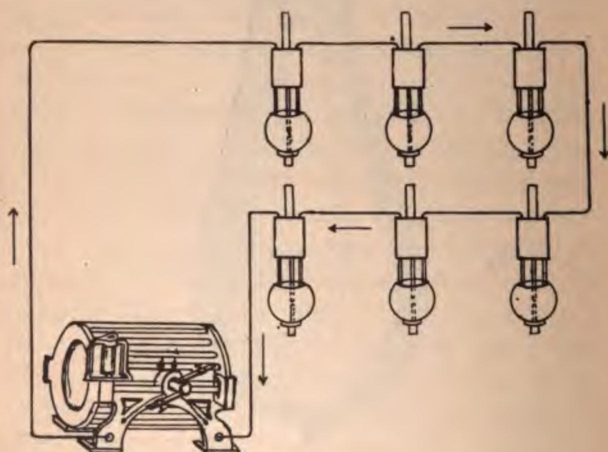


Fig. 1.

There are two ways of running Electric Lamps; first, to connect them up in series which is shown in Fig. 1. In this case the whole current starts

from the dynamo and continues through the carbons of each lamp until it completes the circuit back to the dynamo. This requires very high pressure or (voltage), as in arc lighting; each lamp requires a pressure of about 50 volts, so that you see an ordinary dynamo with the capacity of 3000 volts will run about 60 lamps. But in this way of wiring should anything happen to the first lamp to prevent the current passing through it, there would be no way for the current to go any further, consequently all the lamps would go out. To avoid this difficulty a shunt is employed which acts only when the lamp will not light.

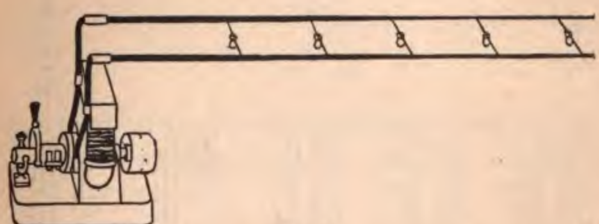


Fig. 2.

In incandescent lighting an entirely different system of wiring is employed, which is to connect the lamps in "multiple arc," as shown in Fig. 2. In this case, there are two mains running from the dynamo, and the lamps are tapped in so that each lamp has the same pressure, but receive only a part of the whole current generated in the dynamo. Should we shut off a lamp or a number of

lamps, the electricity would still pass through the rest of the lamps which were not turned off. To light an incandescent lamp by battery power (take for instance a 4-candle power lamp which required 10 volts to operate it), you would connect your batteries in series (see Fig. 3). It would require five cells of some good closed circuit battery (a bicromate plunge will be a good one), which gave a voltage of about two volts to a cell.

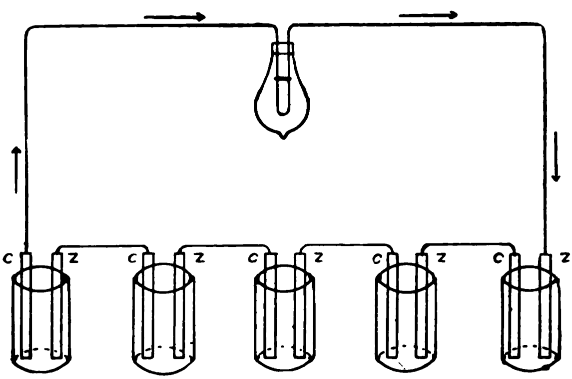


Fig. 3.

In this case, you see by referring to Fig. 3, that the zinc of first cell is connected to the carbon of the next, and so on until you have connected all the cells together, when you connect the wire of the carbon of the first cell and the wire of the zinc of the last cell to the two wires of the lamp, you will then have the ten volts required to run the lamp.

CHAPTER XII.

GLOSSARY OF ELECTRICAL TERMS.

ACCUMULATOR.—See battery and condenser.

AMMETER.—An instrument for measuring current strength.

AMPERE.—The unit of current strength. It is the flow of electricity produced by the pressure of one volt on a resistance of one ohm.

ARC.—The stream of hot gasses and particles of carbon visible between the carbons of an arc lamp.

ARMATURE—That part of a dynamo in which the current is induced. It may be a stationary or moving part, but is generally the latter, and is composed of coils of wire which "cut" the lines of magnetic force produced by the fields. This "cutting" induces a current in the coils.

BATTERY.—One or more cells in which electricity is produced by chemical action. There are two elements of different substances and a liquid in every voltaic battery. A primary battery is one in which the "elements" are placed and used until they are worn out. In a secondary or stor-

age battery or accumulator the "elements" ar placed in the cell and first "formed" by the passage of a current of electricity through them. The cell is then said to be charged and may be used to supply electricity. The term battery is also used to designate a collection of Leyden Jars in which static electricity is toreds.

BRUSH.—A collection of metal sheets or wires which press against the commutator of a dynamo to collect the electricity, or of a motor to supply it. Carbon brushes are coming into use now, especially in railway work.

B. & S.—Brown & Sharp. The wire gauge used in America.

B. W. G.—Birmingham wire gauge. The English wire gauge.

CELL.—The jar in which the elements and liquid of a battery are placed. The term is used also for the jar and its contents.

C. G. S.—The abbreviation of centimetre, gramme, second, and used to designate the so-called absolute system of measurements.

CIRCUIT.—A system of conductors over which electricity passes.

COIL, CLOSED.—The coils of an armature are said to be closed when the end of one is connected to the beginning of the next at the commutator bar. An open coil armature is one in which each coil is independent of the others and has its own commutator bars.

COMMUTATOR.—That part of a dynamo on which the current from the armature is rectified before passing to the external circuit. The current in a given section of an armature alternates and must be made continuous on leaving it. This is done by the commutator, which consists of a series of insulated metal bars connected to the armature wires, and so placed as to feed into different brushes as the current changes.

CONDENSER.—An apparatus for collecting and holding electricity. It consists of alternate layers of conducting sheets and insulating material, the conductors being very close together, and the adjacent ones being charged with the opposite kinds of electricity. Their proximity enables them to hold a larger amount of electricity than they could if alone. Condensers are sometimes called accumulators.

CONDUCTOR.—A substance which will allow the passage of electricity over it. All substances will do this, but some to so small an extent that they are called insulators.

COULOMB.—The unit of electric quantity. It is the amount of electricity which flows past a given point in one second on a circuit conveying one ampere.

CURRENT.—The flow of electricity in a conductor analagous to the flow of water in a pipe. A continuous current is one that does not change its direction, while an alternating current is one that periodically reverses.

CUT OUT.—An arrangement for interrupting a current or for shunting it around some part of a circuit.

DYNAMO.—A machine driven by power which furnishes electricity.

DYNAMOMETER.—An apparatus for measuring the power given out or consumed by a machine. An electro-dynamometer is an instrument for measuring a current by the mutual action of two coils through which it passes.

ELECTRODE.—A pole of a battery.

E. M. F.—An abbreviation for electro-motive force. This is the pressure which forces the electric current through a conductor.

ELECTRO-MAGNET.—A magnet produced by passing a current through a coil of wire around a soft iron core. The core is magnetized while

the current flows, but loses its magnetism when the current stops. This form of magnet may be made much more powerful than a permanent magnet, and is therefore used in place of the latter in dynamos.

FARAD.—The unit of capacity. A condenser that will hold one coulomb at a pressure of one volt has a capacity of one farad.

FILAMENT.—In an incandescent lamp the thread of carbon which becomes luminous when the current is passed through it.

GALVANOMETER. An instrument for detecting and measuring the electric current by the action of a coil of wire upon a magnetic needle.

INDUCTION.—A current is said to be induced in a conductor when it is caused by the conductor cutting lines of magnetic force. A fluctuating current in a conductor will tend to induce a fluctuating current in another running parallel to it. A static charge of electricity is induced in neighboring bodies by the presence of an electrified body. A magnet "induces" magnetism in neighboring magnetic bodies.

INDUCTION COIL.—An arrangement by which an alternating or fluctuating current in a coil of wire will induce an alternating current in a parallel coil.

INSULATOR.—The opposite of a conductor. A body which will not allow the passage of electricity except in such small quantities as to be negligable.

LINES OF FORCE.—Imaginary lines which radiate from a magnet and show by their direction the path which a free magnetic pole would take if left to itself. Conventionally, the strength of of a magnetic field is indicated by the number of these lines. Their form is shown by the well-known experiment with the magnet and iron filings.

MAGNET.—A body possessing the property of attracting iron, steel and a few other metals.

MAGNETIC FIELD.—The space around a magnet in which its power of attraction is exhibited.

MULTIPLE or MULTIPLE ARC. A method of connecting electric conductors by which a number of sources of electricity feed directly into or a number of receivers of electricity take it directly from the same mains.

NEGATIVE.—A conventional term to indicate the direction of flow of a current, or the state of electrification of a body. The negative or terminal of a dynamo is the one at which electricity enters it from the external circuit, while the negative terminal of a lamp or instrument is that connected towards the negative terminal of a dynamo. It is designated by —

OHM.—The unit of electrical resistance.

OHMS LAW.—States that the current in any circuit is equal to the E. M. F. acting on it divided by its resistance.

PERMANENT MAGNET.—A piece of hardened steel which retains its magnetism after the magnetizing influence is removed.

PARALLEL.—See Multiple.

POLE.—Those parts of a magnet which show the strongest magnetic force. In a bar magnet this is generally a short distance from the ends. The pole of a dynamo or battery is one of its terminals.

POSITIVE.—A conventional term to show the direction of a current. In a dynamo or battery it is the terminal at which the electricity leaves it. It is designated by +.

POTENTIAL.—Power to do work. It is commonly used as synonymous with electro-motive force in speaking of dynamos or batteries.

RESISTANCE.—The opposition offered by a body to the passage of electricity through it.

RHEOSTAT.—An apparatus for throwing a variable resistance into a circuit at will.

SERIES.—Two or more conductors are said to be in series when they are so connected that the same current that passes through one passes through the other.

SHORT CIRCUIT.—An indefinite term used generally in the case of dynamos and batteries for a resistance between the terminals lower than the machine or battery is calculated to stand or run on in practice. With lamps the term is used for a low resistance between the terminals, which deprives it of the most of the current.

SHUNT.—A shunt is a conductor connected around another in such a way that it deprives the first of a part of the current.

SOLENOID.—A hollow coil of wire.

TERMINAL.—The point at which the electricity enters or leaves an electrical apparatus.

VOLT.—The unit of electro-motive force or pressure analogous to the head of water in hydraulics.

VOLTMETER.—An instrument for measuring the voltage or pressure on a circuit.

WATT.—The unit of work. The watts developed in a circuit are equal to the current multiplied by the E. M. F. 746 watts equal one horse power.

WATTMETER.—An instrument for measuring the electrical energy in a circuit.

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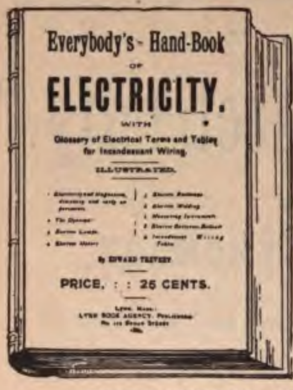

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